JC09 Rec'd PCT/PTO 18 DEC 2001

BAKER BOTTS L.L.P.

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35.U.S.C. 371

EXPRESS MAIL LABEL No. EF377398454US	DATE 12/18/01
ATTORNEY'S DOCKET NO. A34864-PCT-USA	
U.S. APPLICATION NO. t/b/a 10/018382	

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE00/02012	June 19, 2000	June 30, 1999

TITLE OF INVENTION ELECTROMECHANICAL CONNECTION BETWEEN ELECTRONIC CIRCUIT SYSTEMS AND SUBSTRATES, AND METHOD FOR PRODUCING THIS

APPLICANT(S) FOR DO/EO/US Holger Huebner and Vaidyanathan Kripesh

Applicant herewith submits to the United States Designated /Elected Office (DO/EO/US) the following items and other information:

1. [✓] This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. [ ] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(I).
4. [✓] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [✓] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [✓] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [✓] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] A copy of the International Search Report (PCT/ISA/210)
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [✓] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. [✓] A copy of the International Preliminary Examination Report (PCT/IPEA/409)
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [✓] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [✓] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [ ] Other items or information:
    a. [✓] a copy of the International Search Report (PCT/ISA/210)
    b. [✓] a copy of the International Preliminary Examination Report (PCT/IPEA/409)

Comparison document; English and German versions of application; cover page of PCT international application PCT/DE00/02012; formal drawing (Figs. 1-4); postcard; IDS (two copies) PTO Form 1449; cited references; and check in the amount of $1028.00.

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INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE00/02012	June 19, 2000	June 30, 1999

17. [ ] The following fees are submitted:

CALCULATIONS PTO USE ONLY

Basic National Fee (37 CFR 1.492(a)(1)-(5):

Neither international preliminary examination fee (37 CFR 1.482)

Nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO (1.492(a)(3)) $1,040

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO (1.492(a)(5) $890.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO(1.492(a)(2)) $740.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) (1.492(a)(1)) $710.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) $ 100.00

ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 740	
Surcharge of $130.00 for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 C.F.R. 1.492)(e)).				$	
Claims	**Number Filed**	**Number Extra**	**Rate**	$	
Total Claims	36 -20=	16	X $ 18.00	$ 288	
Independent Claims	1 -3=	0	X $ 84.00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $280.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 1,028	
Reduction by ½ for filing by small entity, if applicable.				$	
SUBTOTAL =				$ 1,028	
Processing fee of $130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 1,028	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 1,028	
				Amt. refunded	$
				charged	$

a. [✓] A check in the amount of $1,028.00 to cover the above fees is enclosed.

b. [ ] Please charge our Deposit Account No. 02-4377 in amount of $________ to cover the above fees. A copy of this sheet is enclosed.

c. [✓] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-4377. A copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:
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12/18/01
Date

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JC13 Rec'd PCT/PTO 18 DEC 2001

BAKER BOTTS LLP

Attorney Docket Number: A34864-PCT-USA

Title: ELECTROMECHANICAL CONNECTION BETWEEN ELECTRONIC CIRCUIT SYSTEMS AND SUBSTRATES, AND METHOD FOR PRODUCING THIS CONNECTION

Use Space Below for Additional Information:

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s)	:	Huebner et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	ELECTROMECHANICAL CONNECTION BETWEEN ELECTRONIC CIRCUIT SYSTEMS AND SUBSTRATES, AND METHOD FOR PRODUCING THIS CONNECTION
Examiner	:	To Be Assigned
Group Art Unit	:	To Be Assigned

Assistant Commissioner for Patents
Washington, DC 20231

PRELIMINARY AMENDMENT

Sir:

Kindly amend the above-identified application before examination as follows:

IN THE SPECIFICATION:

Please substitute the originally-filed specification with the Substitute Specification which is enclosed herewith. A comparison document showing the differences between the translation of the originally-filed specification and the enclosed Substitute Specification is also enclosed herewith.

IN THE CLAIMS:

Please cancel original claims 1-34 in the underlying PCT application, without prejudice.

Please add new claims 35-70, as follows:

35. An electromechanical connection between electronic circuit systems and substrates, comprising the electronic circuit system and substrate mechanically connected to one another, and electrical connection elements which face one another on the electronic circuit system connected in an electrically conductive manner by means of microcapsules formed from grains which are coated with a dielectric and which are at least partially electrically conductive, wherein the dielectric of the microcapsules is broken open at least on areas which face the electrical connection elements to provide exposed areas of the grains, and an electrically conductive soldered joint is formed between the exposed areas of the grains and the electrically conductive connection elements.

36. The electromechanical connection according to claim 35, wherein the mechanical connection between the electronic circuit system and substrate is made by means of an adhesive.

37. The electromechanical connection according to claim 36, wherein the adhesive is formed from a polymer.

38. The electromechanical connection according to claim 36, wherein the microcapsules are embedded in the adhesive.

39. The electromechanical connection according to claim 35, wherein the mechanical connection between electronic circuit system and substrate is formed by a soldered joint between connection elements which are inactive in the intended electronic functioning of electronic circuit system.

40. The electromechanical connection according to claim 35, wherein the grains are electrically conductive metal grains selected from the group of metals consisting of copper, nickel, silver, and gold.

41. The electromechanical connection according to claim 35, wherein the grains are electrically conductive metal grains of a solderable metal alloy.

42. The electromechanical connection according to claim 35, wherein the grains are metallized insulating grains.

43. The electromechanical connection according to claim 42, wherein the grains are silver-plated tin oxide grains.

44. The electromechanical connection according to claim 35, wherein the dielectric is an insulating enamel.

45. The electromechanical connection according to claim 44, wherein the insulating enamel is a soldering flux.

46. The electromechanical connection according to claim 35, wherein the electrically conductive soldered joint between the connection elements is formed by layers of solder which are provided on the connection elements to form intermetallic phases comprising material of the electrically conductive grains of the microcapsules and the layers of solder.

47. The electromechanical connection according to claim 46, wherein a metal selected from the group consisting of tin, indium and gallium is used as the material for the layers of solders.

48. The electromechanical connection according to claim 46, wherein a metal alloy having a low melting point is used as the material for the layers of solder.

49. The electromechanical connection according to claim 47, wherein the layers of solder comprise layers of tin which have been deposited selectively without the use of an electric current.

50. The electromechanical connection according to claim 35, wherein the electrical connection elements comprise a metallic material which is matched to the metallic material of the conductive grains.

51. The electromechanical connection according to claim 50, wherein the connection elements comprise a metal selected from the group consisting of copper and nickel.

52. The electromechanical connection according to claim 35, wherein the microcapsules are provided in a single layer, said microcapsules being of a uniform size and embedded in a polymer film.

53. The electromechanical connection according to claim 35, wherein the grains are electrically conductive metal grains covered with an insulating enamel, which grains at least in part consist of a solder metal.

54. The electromechanical connection according to claim 53, wherein the electrically conductive grain of the microcapsules consist entirely of solder metal.

55. The electromechanical connection according to claim 53, wherein the solder metal is selected from the group consisting of tin, indium, and gallium.

56. The electromechanical connection according to claim 53, wherein the solder metal is a soft-solder alloy.

57. The electromechanical connection according to claim 53, wherein a solderable metal is used for the connection elements of electronic circuit system.

58. The electromechanical connection according to claim 57, wherein the solderable metal is selected from the group consisting of copper, nickel, silver, and gold.

59. The electromechanical connection according to claim 53, wherein the electrically conductive grains of the microcapsules are formed from an electrically conductive metal core which is covered with a solder material.

60. The electromechanical connection according to claim 59, wherein the electrically conductive metal core is comprised of copper.

61. The electromechanical connection according to claim 59, wherein the covering of the core is comprised of tin.

62. The electromechanical connection according to claim 35, wherein the electrically conductive grains of the microcapsules have a diameter of about 10 μm.

63. The electromechanical connection according to claim 61, wherein the tin covering of the core has a thickness of about 200 nm.

64. The electromechanical connection according to claim 46, wherein the layers of solder which are applied to the connection elements have a thickness of about 10 μm.

65. A method for producing the electromechanical connection according to claim 35, comprising compressing the microcapsules under a force such that the dielectric

coating on the grains is broken open, and producing the soldered joint by diffusion soldering.

66. The method according to claim 65, further comprising applying layers of solder metal to connection elements in a thickness such that, during a diffusion-soldering process, the solder metal is completely converted into an intermetallic phase.

67. The method according to claim 65, wherein the microcapsules have electrically conductive grains consisting entirely of solder metal, and connection elements which are free of solder metal, further comprising selecting a thickness of the connection elements so that sufficient material is available for a transformation process during the diffusion soldering.

68. The method according to claim 65, wherein the microcapsules have electrically conductive grains comprising an electrically conductive metal core covered with a solder metal, and wherein the connection elements are free of solder metal on electronic circuit system and substrate, further comprising selecting the thickness of the connection elements and the solder metal in such a way that there is sufficient material, during the diffusion soldering for a transformation process.

69. The electromechnical connection according to claim 62, wherein the diameter of the microcapsules is less than 10 μm.

70. The electromechanical connection according to claim 64, wherein the layers of solder have a thickness of less than 10 μm.

REMARKS

This Preliminary Amendment cancels, without prejudice, originally-filed claims 1-34 in underlying PCT Application No. PCT/DE00/02012. New claims 35-70 have been added merely to conform the claims to U.S. Patent and Trademark Office practice and standards, and do not add new matter to the application. Furthermore, the addition of these new claims in no way addresses any issues of patentability, and the new claims are provided to place the application in condition for allowance.

The amendment to the abstract and the substitute specification are provided to correct grammatical and syntactical errors and otherwise to conform the specification and abstract of the above-identified application to the U.S. Patent and Trademark Office practice. No new matter has been introduced to the application.

The amendments to the "Claims" is reflected in the attached "Version With Marked Changes Made."

Favorable consideration on the merits is respectfully requested.

Respectfully submitted,

Dated: December 18, 2001

By: ______________________
Louis S. Sorell
Reg. No. 32,439

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Version With Marked Changes Made

~~I(WE)~~ CLAIM:

35. ~~1.~~ An electromechanical connection between electronic circuit systems ~~(10)~~ and substrates ~~(20), in which an~~comprising the electronic circuit system ~~(10)~~ and ~~a~~ substrate ~~(20) are~~ mechanically connected ~~fixedly~~ to one another, and electrical connection elements ~~(11, 21)~~ which face one another on the electronic circuit system ~~(10) and the substrate (20) are in each case~~ connected in an electrically conductive manner by means of microcapsules ~~(23-1, 23-2), and in which the microcapsules (23-1, 23-2) are~~ formed ~~by~~from grains ~~(23-1)~~ which are coated with a dielectric ~~(23-2)~~ and which are at least ~~in part are~~partially electrically conductive, ~~characterized in that~~wherein the dielectric ~~(23-2)~~ of the microcapsules ~~(23-1, 23-2)~~ is broken open at least on ~~its~~ areas which face the electrical connection elements ~~(11,~~to ~~21), and at the correspondingly~~provide exposed areas of the grains, ~~(23-1)~~and an electrically conductive soldered joint ~~(25 to 28)~~ is formed ~~in each case~~ between the exposed areas of the grains ~~(23-1)~~ and the electrically conductive connection elements ~~(11, 21), which in each case face these areas, of the electronic circuit system (10) and of the substrate (20), respectively~~.

36. ~~2.~~ The electromechanical connection ~~as claimed in~~according to claim ~~1, characterized in that~~35, wherein the ~~mechanically fixed~~mechanical connection between the electronic circuit system ~~(10)~~ and substrate ~~(20)~~ is made by means of an adhesive ~~(24)~~.

37. ~~3.~~ The electromechanical connection ~~as claimed in claims 1 and 2, characterized in that~~according to claim 36, wherein the adhesive ~~(24) used~~ is formed from a polymer.

38. ~~4.~~ The electromechanical connection ~~as claimed in one of claims 1 to 3, characterized in that~~according to claim 36, wherein the microcapsules ~~(23-1, 23-2)~~ are embedded in the adhesive ~~(24)~~.

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39. ~~5.~~ The electromechanical connection ~~as claimed in~~according to claim ~~1, characterized in that~~35, wherein the ~~mechanically fixed~~mechanical connection between electronic circuit system ~~(10)~~ and substrate ~~(20)~~ is formed by a soldered joint between connection elements ~~(11, 21)~~ which are inactive in the intended electronic functioning of electronic circuit system ~~(10) and substrate (20)~~.

40. ~~6.~~ The electromechanical connection ~~as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains ~~(23-1) which are~~ selected from the group of metals consisting of copper, nickel, silver, and gold ~~and are covered with a dielectric (23-2) are used as microcapsules (23-1, 23-2)~~.

41. ~~7.~~ The electromechanical connection ~~as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains ~~(23-1)~~ of a solderable metal alloy~~, which are covered with a dielectric (23-2), are used as microcapsules (23-1, 23-2)~~.

42. ~~8.~~ The electromechanical connection ~~as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are metallized~~,~~ insulating grains ~~(23-1) which are covered with a dielectric (23-2) are used as microcapsules (23-1, 23-2)~~.

43. ~~9.~~ The electromechanical connection ~~as claimed in~~according to claim ~~8, characterized in that~~42, wherein the grains are silver-plated tin oxide grains ~~are used as metallized, insulating grains (23-1)~~.

44. ~~10.~~ The electromechanical connection ~~as claimed in one of claims 6 to 9, characterized in that~~according to claim 35, wherein the dielectric is an insulating enamel ~~is used as the dielectric (23-2) of the microcapsules (23-1, 23-2)~~.

45. ~~11.~~ The electromechanical connection ~~as claimed in claim 10, characterized in that a soldering flux is used as~~according to claim 44, wherein the insulating enamel is a soldering flux.

46. ~~12.~~ The electromechanical connection ~~as claimed in one of claims 1 to 11, characterized in that~~according to claim 35, wherein the electrically conductive soldered joint ~~(25 to 28)~~ between the connection elements ~~(11, 21) of electronic circuit system (10) and substrate (20)~~ is formed by ~~soldering of~~ layers of solder ~~(25, 27)~~ which are provided on the connection elements ~~(11, 21)~~ to form intermetallic phases ~~(26, 28)~~ comprising material of the electrically conductive grains ~~(23-1)~~ of the microcapsules ~~(23-1, 23-2)~~ and the layers of solder ~~(25, 27)~~.

47. ~~13.~~ The electromechanical connection ~~as claimed in~~according to claim ~~12, characterized in that~~46, wherein a metal selected from the group consisting of ~~ten~~tin, indium and gallium is used as the material for the layers of solders ~~(25, 27)~~.

48. ~~14.~~ The electromechanical connection ~~as claimed in~~according to claim ~~12, characterized in that~~46, wherein a metal alloy ~~with~~having a low melting point is used as the material for the layers of solder ~~(25, 27)~~.

49. ~~15.~~ The electromechanical connection ~~as claimed in~~according to claim ~~13 or 14, characterized in that~~47, wherein the layers of solder ~~(25, 27) are~~comprise layers of tin which have been deposited selectively ~~and~~ without ~~using~~the use of an electric current.

50. ~~16.~~ The electromechanical connection ~~as claimed in one of claims 1 to 15, characterized in that~~according to claim 35, wherein the electrical connection elements comprise a metallic material which is matched to the metallic material of the conductive grains ~~(23-1) of the microcapsules (23-1, 23-2) is used as material for the connection elements (11, 21) of electronic circuit system (10) and substrate (20)~~.

51. ~~17.~~ The electromechanical connection ~~as claimed in claim 16, characterized in that~~according to claim 50, wherein ~~(23-1) of the microcapsules (23-1, 23-2) is used as material for~~ the connection elements ~~(11, 21) of electronic circuit system (10) and substrate (20)~~comprise a metal selected from the group consisting of copper ~~or~~and nickel ~~is used as material for the connection elements (11, 21)~~.

52. ~~18.~~ The electromechanical connection ~~as claimed in one of claims 1 to 17, characterized in that~~according to claim 35, wherein the microcapsules are provided in a single layer, ~~of~~said microcapsules ~~(23-1, 23-2)~~being of a uniform size and embedded in a polymer film ~~are provided~~.

53. ~~19.~~ The electromechanical connection ~~as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains ~~(23-1) which are~~ covered with an insulating enamel ~~(23-2) and~~, which grains at least in part consist of a solder metal ~~are used as microcapsules (23-1, 23-2)~~.

54. ~~20.~~ The electromechanical connection ~~as claimed in~~according to claim ~~19, characterized in that~~53, wherein the electrically conductive grain ~~(23-1)~~ of the microcapsules ~~(23-1, 23-2)~~ consist entirely of solder metal.

55. ~~21.~~ The electromechanical connection ~~as claimed in~~according to claim ~~19 or 20, characterized in that a~~53, wherein the solder metal is selected from the group consisting of tin, indium, and gallium ~~is used for the electrically conductive grains (23-1)~~.

56. ~~22.~~ The electromechanical connection ~~as claimed in claim 19 or 20, characterized in that~~according to claim 53, wherein the solder metal is a soft-solder alloy ~~is used for the electrically conductive grains (23-1)~~.

57. ~~23.~~ The electromechanical connection ~~as claimed in one of claims 19 to 22, characterized in that~~according to claim 53, wherein a solderable metal is used for the connection elements ~~(11, 21)~~ of electronic circuit system ~~(10) and substrate (20)~~.

58. ~~24.~~ The electromechanical connection ~~as claimed in~~according to claim ~~23, characterized in that a~~57, wherein the solderable metal is selected from the group consisting of copper, nickel, silver, and gold ~~is used as the solderable metal for the connection elements (11, 21)~~.

59. ~~25.~~ The electromechanical connection ~~as claimed in~~according to claim ~~19, characterized in that~~53, wherein the electrically conductive grains ~~(23-1)~~ of the microcapsules ~~(23-1, 23-2)~~ are formed from an electrically conductive metal core which is covered with a solder material.

60. ~~26.~~ The electromechanical connection ~~as claimed in claim 25, characterized in that~~according to claim 59, wherein the electrically conductive metal core is comprised of copper ~~is used as material for the electrically conductive metal core~~.

61. ~~27.~~ The electromechanical connection ~~as claimed in claim 25 and/or 26, characterized in that tin is used as solder material for~~according to claim 59, wherein the covering of the core is comprised of tin.

62. ~~28.~~ The electromechanical connection ~~as claimed in one of claims 1 to 27, characterized in that~~according to claim 35, wherein the electrically conductive grains ~~(23-1)~~ of the microcapsules ~~(23-1, 23-2)~~ have a diameter of ~~the order of magnitude of 10 µm, preferably less than~~about 10 µm.

63. ~~29.~~ The electromechanical connection ~~as claimed in~~according to claim ~~27, characterized in that~~61, wherein the tin covering of the core has a thickness of ~~the order of magnitude of~~about 200 nm.

64. ~~30.~~ The electromechanical connection ~~as claimed in one of claims 1 to 18, characterized in that~~according to claim 46, wherein the layers of solder which are applied to the connection elements ~~(11, 21)~~ have a thickness of ~~the order of magnitude of~~about 10 ~~µm, preferably less than 10~~ µm.

65. ~~31.~~ A method for producing the electromechanical connection ~~as claimed in one of claims 1 to 30, characterized in that, after~~according to claim 35, comprising compressing the microcapsules ~~(23-1, 23-2) embedded in an adhesive (24) or a polymer film have been introduced between electronic circuit system (10) and substrate (20), the microcapsules (23-1, 23-2) between the connection elements (11, 21) of the circuit system (10) and of the substrate (20) are compressed~~ under ~~such~~ a force such that the dielectric ~~(23-2)~~coating on ~~electrically conductive~~the grains ~~(23-1) situated between connection elements (11, 21) which face one another~~ is broken open, and producing the soldered joint ~~(25 to 28) in each case between those areas of the grains (23-1) which face the connections (11, 21) and the connections (11, 21) is produced~~ by diffusion soldering.

66. ~~32.~~ The method ~~as claimed in~~according to claim ~~31, characterized in that~~65, further comprising applying layers of solder metal ~~(25, 27) are applied~~ to connection elements ~~(11, 21)~~ in a thickness ~~which is~~ such that, during a diffusion-soldering process ~~between metals of the electrically conductive grains (23-1) or grains (23-1) in the form of metallized insulators and the solder metal~~, the solder metal is completely converted into an intermetallic phase ~~(26, 28)~~.

67. ~~33.~~ The method ~~as claimed in~~according to claim ~~31, characterized in that, when using~~65, wherein the microcapsules ~~(23-1, 23-2) whose~~have electrically conductive grains ~~(23-1)~~ ~~consist~~consisting entirely of solder metal, and connection elements ~~(11, 21)~~ which are free of solder metal ~~on electronic circuit system (10) and substrate (20)~~, ~~the~~further comprising selecting a thickness of the connection elements ~~(11, 21) is selected in such a way~~so that sufficient material is available for ~~the~~a transformation process during the diffusion soldering.

68. ~~34.~~ The method ~~as claimed in~~according to claim ~~31, characterized in that, when using~~65, wherein the microcapsules ~~(23-1, 23-2) whose~~have electrically conductive grains ~~(23-1)~~ ~~comprise~~comprising an electrically conductive metal core covered with a solder metal, and wherein the connection elements ~~(11, 21) which~~ are free of solder metal on electronic circuit system ~~(10)~~ and substrate ~~(20)~~, further comprising selecting the thickness of the connection elements ~~(11, 21)~~ and ~~of~~ the solder metal ~~is selected~~ in such a way that ~~their material~~there is sufficient material, during the diffusion soldering~~,~~ for ~~the~~a transformation process ~~between connection element material and core metal having the solder metal.~~.

69. The electromechnical connection according to claim 62, wherein the diameter of the microcapsules is less than 10 µm.

70. The electromechanical connection according to claim 64, wherein the layers of solder have a thickness of less than 10 µm.

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
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(43) Internationales Veröffentlichungsdatum
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(81) **Bestimmungsstaaten** *(national)*: JP, KR, US.

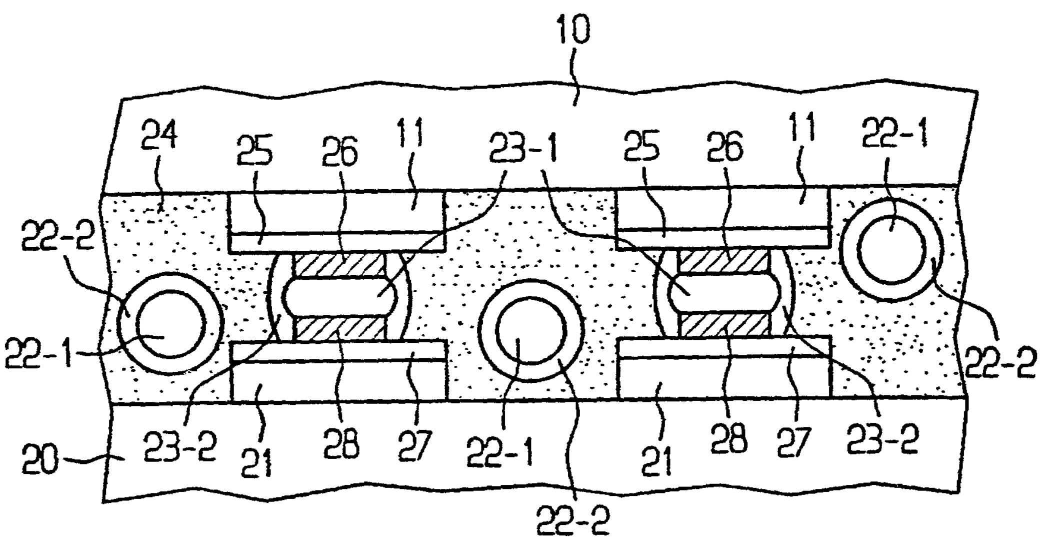
(84) **Bestimmungsstaaten** *(regional)*: europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Veröffentlicht:
— *Mit internationalem Recherchenbericht.*

[Fortsetzung auf der nächsten Seite]

(54) **Title:** ELECTRICAL-MECHANICAL CONNECTION BETWEEN ELECTRONIC CIRCUIT SYSTEMS AND SUBSTRATES AND METHOD FOR THE PRODUCTION THEREOF

(54) **Bezeichnung:** ELEKTRISCH-MECHANISCHE VERBINDUNG ZWISCHEN ELEKTRONISCHEN SCHALTUNGSSYSTEMEN UND SUBSTRATEN, SOWIE VERFAHREN ZU DEREN HERSTELLUNG



(57) **Abstract:** The invention relates to an electrical-mechanical connection between electronic circuit systems (10) and substrates (20). According to the invention, the electronic circuit systems (10) and substrates (20) are connected to one another in a mechanically fixed manner and the electrical connection elements (11, 21) thereof are connected in an electrically conductive manner via microcapsules (23-1, 23-2) comprised of granules (23-1) which are at least, in part, electrically conductive and which are coated with a dielectric (23-2). In addition an electrically conductive soldered connection (25 to 28) exists between microcapsules (23-1, 23-2) with a forced open dielectric (23-2) and the electrical connection elements (11, 21).

[Fortsetzung auf der nächsten Seite]

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TO ALL WHOM IT MAY CONCERN:

Be it known that WE, Holger Huebner and Vaidyanathan Kripesh, citizens of Germany and India respectively, residing in Germany and India respectively, whose post office addresses are Hamsterweg 10, 85598 Baldham, Germany; and L-5/E Sarvamangala Colon, Ind-Chennai 600083, Ashok Nagar, India, respectively, have invented an improvement in:

ELECTROMECHANICAL CONNECTION BETWEEN ELECTRONIC CIRCUIT SYSTEMS AND SUBSTRATES, AND METHOD FOR PRODUCING THIS CONNECTION

of which the following is a

SPECIFICATION

~~BACKGROUND OF THE INVENTION~~

FIELD OF THE INVENTION

[0001] The present invention relates to an electromechanical connection between electronic circuit systems and substrates ~~in accordance with the preamble of patent claim 1~~ and to a method for its production~~in accordance with patent claim 31.~~.

BACKGROUND OF THE INVENTION

[0002] In the context of the present invention~~,~~ the term electronic circuit systems is understood as meaning solid-state circuit systems, in particular integrated semiconductor circuits. Specifically, the term system indicates, for example in an integrated

semiconductor circuit, the semiconductor material body which holds the electronic functional circuit elements, such as transistors, diodes, capacitors, etc., and the metallic conductor tracks and connection elements which are situated on this body and connecting the functional circuit elements. The connection elements may be flat applications of metal, known as pads, or spherical metallic elements, known as bumps. Further, in~~In~~ the context of the present invention, the term substrates is understood as meaning circuit boards, such as printed circuits or printed-circuit boards. Substrates of this type also have connection elements of the above-mentioned type, generally in the form of pads.

~~**[0003]** The connection elements may be flat applications of metal, known as pads, or spherical metallic elements, known as bumps.~~

~~**[0004]** In the context of the present invention, the term substrates is understood as meaning circuit boards, such as printed circuits or printed-circuit boards. Substrates of this type also have connection elements of the above-mentioned type, generally in the form of pads.~~

~~**[0005]** It is known to produce electromechanical connections of the type under discussion by means of an adhesive which contains electrically conductive grains. An electromechanical connection of this type is~~ explained ~~below with reference to Fig. 1.~~

~~**[0006]** Fig. 1 diagrammatically depicts an electronic circuit system 10, for example an integrated semiconductor circuit, which is electrically and mechanically connected to a substrate 20, for example a printed-circuit board. Connection elements in the form of pads are present on the circuit system 10, and connection elements 21, which are likewise in the form of pads, are present on the substrate 20.~~

[0003] ~~**[0007]**~~ It is known to produce electromechanical connections of the type under discussion by means of an adhesive which contains electrically conductive grains. An electromechanical connection of this type is ~~explained~~described below with reference to ~~Fig. 1.~~Figure 1, which~~Fig. 1~~ diagrammatically depicts an electronic circuit system 10, ~~for example~~e.g., an integrated semiconductor circuit, which is electrically and mechanically connected to a substrate 20, ~~for example~~such as a printed-circuit board. Connection elements in the form of pads are present on the circuit system 10, and connection elements ~~21, which are likewise in the form of pads,~~21 which are also in the form of pads are present on the substrate 20. The circuit system 10 and the substrate 20 are connected to one another using the ~~flip~~Flip-~~chip~~Chip ~~technology~~Technology in such a manner that the pads 11 and 21 come to lie facing one another, with an adhesive 24, which contains electrically conductive grains 22 and 23 and is indicated by dot-dashed lines~~,~~ between them. The adhesive 24 may~~, for example,~~ be a polymer, ~~while~~and the conductive grains may consist of silver.

~~**[0008]** In a connection of the above-mentioned type, electrically conductive grains, which are in this case denoted by 22, come to lie in the lateral spaces between the pads 11 and 21, and conductive grains which are denoted by 23 come to lie in the vertical spaces between pads 11 and 21 which face one another.~~

[0004] ~~**[0009]**~~ In a connection of the above-mentioned type, the electrically conductive grains~~, which are in this case denoted by 22,~~ come to lie in the lateral spaces between the pads 11 and 21, and conductive grains ~~which are denoted~~ by 23 come to lie in the vertical spaces between pads 11 and 21 which face one another. Pressing the circuit system 10 and substrate 20 together ensures that the electrically conductive grains 23 between pads

11 and 21 which face one another come into electrically conductive contact with these pads, thus producing an electrical connection between circuit system 10 and substrate 20. ~~By contrast, the~~The electrically conductive grains 22 in the lateral spaces between pads 11 and 21 do not come into electrically conductive connection with the pads, ~~so that in this respect~~hence there is no short-circuiting connection between pads. An electrical connection of the type described is anisotropically conductive~~,~~ in that an electrically conductive connection is produced in the vertical direction by electrically conductive grains ~~22~~23 between pads 11 and 21 which face one another, but is not produced in the lateral direction by electrically conductive grains 22 in lateral spaces between pads 11 and 21.

[0005] ~~[0010]~~ To indicate that the electrically conductive grains 23 between pads 11 and 21 which face one another can be deformed during compression, they are diagrammatically indicated in an oval shape~~, while the~~. The grains 22 in the lateral spaces between pads 11 and 21 remain undeformed and are therefore diagrammatically indicated in the shape of a circle.

~~[0011] In the type of electromechanical connection described above, the following conditions have to be satisfied for reliable operation.~~

[0006] ~~[0012] Firstly, the adhesive 24,~~In the type of electromechanical connection described above, ~~the following~~certain conditions have to be satisfied for reliable operation. First, during setting and ~~when~~while the circuit system 10 and substrate 20 are operating, the adhesive 24 has to develop sufficiently high shrinkage forces to ensure permanent compression~~ and therefore~~, in order to provide a reliable mechanical

connection between circuit system 10 and substrate 11. However, adhesives do not generally have good properties in terms of adhesion and resistance to moisture, and consequently a connection of this type is not sufficiently reliable. Particularly in the event of fluctuating thermal loads, high shear forces may arise in the adhesive ~~join~~joint, with the result that the adhesive may break open and~~, as a result,~~ the electrical connection through the electrically conductive grains 23 may be broken. Furthermore, moisture which ~~penetrates~~may penetrate into the ~~join may~~joint, when heated, may cause entire areas of the circuit system 10 to break away from the substrate 20. These drawbacks ~~are~~may be offset by ~~the advantage that~~ adhesives that do not need to be structured.

[0007] ~~[0013] Secondly~~Second, the amount of electrically conductive grains 22, 23 in the adhesive 24 must be sufficiently large to ensure that there is at least one electrically conductive grain 23 between pads 11, 21 which face one another, in order to guarantee an electrically conductive connection. On the other hand, the amount of these grains must not be so high that there is a risk of electrical short circuits being caused by electrically conductive grains 22 in lateral spaces between pads 11, 21. This problem assumes greater importance as~~As~~ the level of integration increases and ~~therefore~~ the electrically conductive structures become smaller, as do the distances between them on integrated semiconductor circuits and matching structures on substrates connected to the circuits, such as for example printed-circuit boards~~, the latter problem becomes increasingly important.~~.

~~[0014] As the level of integration increases and therefore the electrically conductive structures become smaller, as do the distances between them on integrated semiconductor~~

~~circuits and matching structures on substrates connected to the circuits, such as for example printed circuit boards, the latter problem becomes increasingly important.~~

[0008] ~~[0015]~~ To counteract this problem, it is known from "Flip Chip Technologies" by John H. Lau, McGraw-Hill, 1996, pages 289-299, to use microcapsules which are embedded in an adhesive and comprise electrically conductive grains and a dielectric surrounding them, for example in the form of an insulating plastic. A microcapsule of this type comprising an electrically conductive grain 22-1 (or 23-1) and a dielectric 22-2 (or 23-2) surrounding it is illustrated on an enlarged scale in ~~Fig.~~ Figure 2.

[0009] ~~[0016]~~ In an electromechanical connection using conductive grains surrounded by a dielectric in an adhesive also requires the circuit system 10 and the substrate 20 to be pressed together, as shown in ~~Fig.~~Figure 1. As a result of the pressure which is generated by this operation and the setting of the adhesive 24, the microcapsules 23-1, 23-2 between pads 11, 21 which face one another are compressed~~, with the result that~~. This results in the dielectric 23-2 ~~is~~being broken open and~~, as a result,~~ an electrically conductive connection is formed via the electrically conductive grains 23-1. This state of affairs is ~~diagrammatically~~ illustrated in ~~Fig.~~Figure 3 in the form of a deformed microcapsule 23-1, 23-2 between two pads 11, 21. Although in an electromechanical connection of ~~this~~the type produced by means of ~~microcapsules of the type~~microcapsules described above the problem of lateral electric short circuits via microcapsules 22-1, 22-2 situated in the lateral spaces between pads 11, 21 is virtually eliminated, the problems described above in connection with the adhesive remain as before.

~~[0017] Although in an electromechanical connection of this type produced by means of microcapsules of the type described above the problem of lateral electric short circuits via microcapsules 22-1, 22-2 situated in the lateral spaces between pads 11, 21 is virtually eliminated, the problems described above in connection with the adhesive remain as before.~~

SUMMARY OF THE INVENTION

[0010] ~~[0018]~~ The present invention ~~is based on the object of providing~~provides an electromechanical connection ~~of the type under discussion~~ which~~,~~ is both mechanically and electrically stable and prevents electric short circuits even with fine electrically conductive structures on electronic circuit systems and substrates~~, is both mechanically and electrically stable and prevents electric short circuits~~. Specifically, ~~With~~ an electromechanical connection ~~of the generic type, this object is achieved, according to the invention, by the measures given in the characterizing part of patent claim 1.~~is formed between electronic circuit systems and substrates which are mechanically connected. The electrical connection elements which face one another on the electronic circuit system and substrate are connected in an electronically conductive manner by means of microcapsules which are in the form of grains coated with a dielectric which is broken open on its areas which face the electrical connection elements. At the exposed areas of the grains an electrically conductive soldered joint is formed between the exposed areas of the grains and the electrically conductive connection elements which face these areas.

~~[0019] With an electromechanical connection of the generic type, this object is achieved, according to the invention, by the measures given in the characterizing part of patent claim 1.~~

~~[0020] A method for producing an electromechanical connection according to the invention is characterized by the measures given in patent claim 31.~~

~~[0021] Refinements of the electromechanical connection according to the invention and of the method according to the invention form the subject matter of corresponding subclaims.~~

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] ~~[0022]~~ The present invention is ~~explained~~described in ~~more~~greater detail below ~~on the basis of exemplary embodiments~~ in ~~conjunction~~connection with the ~~figures of the drawing~~drawings, in which:

Figures 1 to 3 ~~show the~~illustrate known ~~embodiments~~features of the invention which have ~~already~~ been ~~explained~~described ~~above,~~hereinabove; and

~~Fig. 4 shows a diagrammatic illustration, corresponding to that shown in Fig. 1, of~~Figure 4 illustrates an electromechanical connection ~~in order to explain embodiments in accordance with the invention.~~ corresponding to that shown in ~~Fig. 1, of~~Figure 1 but which embodiment is in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0012] ~~[0023] The essence of the invention is to be seen as residing in the fact that~~In accordance with the present invention, a metallic solder joint is produced at least at the

locations of the electrical connections, in addition to a compressive connection to produce the electrical connection between an electronic circuit system and a substrate~~, a metallic solder joint is produced at least at the locations of the electrical connections~~.

~~[0024] In Fig. 4, on the basis of which embodiments of the invention are explained, identical elements to those shown in Figures 1 to 3 are provided with identical reference symbols.~~

[0013] ~~[0025] As has already been~~In Figure 4, ~~In Fig. 4, on the basis of which embodiments of the invention are explained,~~ identical elements to those shown in Figures 1 to 3 are provided with identical reference symbols. As explained in connection with ~~reference to Fig.~~Figure 1, ~~the arrangement shown in Fig.~~Figure 4 ~~is likewise~~illustrates an electromechanical connection between an electronic circuit system ~~10,~~10 (for example an integrated semiconductor circuit system), and a substrate ~~20,~~20 (for example an electrical printed-circuit board). Electronic circuit system 10 and substrate 20 ~~once again~~also have the connection elements in the form of pads 11 and 21.

[0014] ~~[0026] The~~A purely mechanical connection ~~takes place~~occurs by means of the adhesive 24 which is indicated by dot-dashed lines, for example a polymer~~, in which, however~~. However, unlike ~~in~~ the known embodiment shown in ~~Fig.~~Figure 1, it is not purely metallic electrically conductive particles 22, 23, but rather microcapsules 22-1, 22-2, 23-1, 23-2 which are suitable for a soldering operation that are embedded. Embodiments of these microcapsules are explained in more detail below.

[0015] ~~[0027]~~ It should be noted that the invention is not restricted to embodiments used with an adhesive 24 to produce the purely mechanical connection between electronic

circuit system 10 and substrate 20. Embodiments in which a connection is produced by means of a soldering operation without adhesive, which is described in even more detail below, are also possible. This can take place by means of pads 11, 21 which are inactive for the intended electronic operation of electric circuit system 10 and substrate. In this context, the term "inactivity" means that pads of this type are not electrically connected to electronic functional elements in electronic circuit system 10 or on or in substrate 20.

~~[0028] A first embodiment of a soldered joint in the context of the invention is explained below.~~

[0016] ~~[0029]~~ In ~~this~~oneA first embodiment of a soldered joint in the context of the ~~invention is explained below.~~present ~~embodiment~~invention, the microcapsules comprise electrically conductive grains 22-1, 23-1 which are covered with a dielectric 22-2, 23-2 and may consist of a metal selected from the group consisting of copper, nickel, silver, gold, a solderable metal alloy or an insulator, for example tin oxide, which is covered with an electrically conductive metal, ~~for example~~e.g., silver. The way in which microcapsules ~~of the latter type~~ can be produced is known, for example, from "JOURNAL OF MATERIALS SCIENCE" 28 (1993), pages 5207-~~5210.~~5210 which is incorporated herein by reference. The dielectric 22-2, 23-2 used may be an insulating enamel, which may also act as a soldering flux.

~~[0030] The dielectric 22-2, 23-2 used may be an insulating enamel, which may also act as a soldering flux.~~

[0017] ~~[0031]~~ For the soldering operation, layers of solder 25, 27, for which a metal selected from the group consisting of tin, indium, gallium, or a metal alloy with a low

melting point may be used, are provided on the pads 11, 21 in order to produce the electrically conductive connection between electronic circuit system 10 and substrate 20. The layers of solder 25, 27 are preferably produced by selective electroless deposition on the pad surfaces, so that it is possible to produce sufficiently planar surfaces.

[0018] ~~[0032]~~ In accordance with the method according to the present invention, microcapsules 22-1, 22-2, 23-1, 23-2, which are embedded in the adhesive 24 or a polymer film, which is not specifically shown in ~~Fig.~~Figure 4, are introduced between the electronic circuit system 10 and the substrate ~~20, and they~~20. They are then compressed together under such a force that the dielectric 23-2 of microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another is broken open. After ~~the~~ compression, the arrangement is heated to a temperature which ~~lies~~is above the melting point of the solder material of the layers of solder 25, 27. In the process~~,~~ the molten solder comes into contact with material of the electrically conductive grains 23-1 of the microcapsules 23-1, 23-~~2,~~2 and a metallic bond ~~with~~having good electrical conductivity is produced.

[0019] ~~[0033]~~ Microcapsules 22-1, 22—2 in lateral spaces between pads 11, 21 remain unaffected by the compression operation and therefore their dielectric 22-2 remains intact~~, with the~~. The result of this is that lateral short circuits are prevented. Therefore, the electromechanical connection according to the invention is anisotropically conductive in the sense explained above.

~~[0034] It is particularly advantageous if a diffusion-soldering method is used for the soldering. In this method, a metallic bond which is able to withstand high temperature is produced using a low-melting solder as a result of the solder metal forming an~~

~~intermetallic phase, which is able to withstand high temperatures and is very mechanically stable, with high-melting metals which are to be connected. In the process, the low-melting solder metal is completely transformed, i.e. passes completely into the intermetallic phase. A soldering method of this type is known per se, for example from US-A 5 053 195.~~

[0020] ~~[0035]~~ ~~For this method,~~It is particularly preferred~~It is particularly advantageous~~ if a diffusion-soldering method is used for the soldering. In this method, a metallic bond which is able to withstand high temperature is produced using a low-melting solder as a result of the solder metal forming an intermetallic phase~~,~~ which is able to withstand high temperatures and is very mechanically stable, with high-melting metals which are to be connected. In the process, the low-melting solder metal is completely transformed, i.e. passes completely into the intermetallic phase. A soldering method of this type is ~~known per se, for example from US-A 5 053 195.~~disclosed in United States Patent No. 5,053,195, wherein the layers of solder 25, 27 have a thickness of the order of magnitude of about 10 μm, preferably of less than ~~10 μm. They~~about 10 μm, and consist, for example, of tin. The electrically conductive grains 23-1 or the metallic layers of grains in the form of metallized insulators, and if appropriate the pads 11, 21, consist, ~~for example~~e.g., of copper or nickel. When contact is made between the metal of the grains during the diffusion-soldering method, the tin is completely transformed into intermetallic phases, which are denoted by 26, 28 in ~~Fig.~~Figure 4. As has ~~already~~ been explained above, the joint which is formed in the process has a significantly higher melting point than the solder metal and better mechanical properties, such as high tensile strength and freedom from creep. It is important~~In a development of the invention, it is~~

~~essential~~ in a soldering process of this type that a single layer of microcapsules is situated between the pads 11, 21 and the pad surfaces are sufficiently planar. Then, all the microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another are compressed, so that their electrically conductive grains 23-2 or their electrically conductive parts come into contact with the solder metal.

~~[0036] In a development of the invention, it is essential in a soldering process of this type that a single layer of microcapsules is situated between the pads 11, 21 and the pad surfaces are sufficiently planar. Then, all the microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another are compressed, so that their electrically conductive grains 23-2 or their electrically conductive parts come into contact with the solder metal.~~

[0021] ~~[0037] The~~A single-layer structure can be produced particularly successfully if – ~~as stated above –~~the microcapsules 22-1, 22-2, 23-1, 23-2 are previously embedded in a polymer film. The ~~way~~manner in which films with embedded microcapsules of this type can be built up and produced ~~in detail~~ is ~~known per se, for example from~~taught in 1992 "IEEE", pages 473 to 480 and 487 to 491. A film of this type ensures the lateral insulation of the microcapsules 22-1, 22-2, 23-1, 23-2 and can act as a spacer. Shaped parts which match the surfaces which are to be connected can be produced. The adhesive 24 can then be dispensed with, if appropriate.

[0022] ~~[0038]~~ It should be mentioned once again that the configuration described above is not specifically illustrated in ~~Fig.~~Figure 4. Also, soldered joints between pads 11, 21 which are inactive in the sense mentioned above and microcapsules 23-1, 23-2 without any adhesive 24 being present are not specifically illustrated in ~~Fig.~~Figure 4. However,

in ~~Fig.~~ Figure 4 it would be possible, for example, for the two pads 11, 21 shown on the right-hand side of the drawing to be regarded as "inactive" pads and for the two pads 11, 21 situated on the left-hand side of the drawing to be regarded as "active" pads.

~~[0039] In a further embodiment of the invention, it is possible to use microcapsules 22-1, 22-2, 23-1, 23-2 which at least in part consist of a solder metal.~~

~~[0040] According to one variant of this embodiment, the electrically conductive grains 22-1, 23-1 consist entirely of solder metal, in which case a metal selected from the group consisting of tin, indium, gallium or a soft-solder alloy can be used as solder metal.~~

~~[0041] In this case, a solderable metal which may be a metal selected from the group consisting of copper, nickel, silver or gold is used as material for the pads 11, 21 of the electronic circuit system 10 and substrate 20.~~

[0023] ~~[0042]~~ ~~In~~In a further preferred embodiment of the present~~In a further embodiment of the~~ invention, it is possible to use microcapsules 22-1, 22-2, 23-1, 23-2 which at least in part consist of a solder metal. According to a~~According to one~~ variant of this embodiment, the electrically conductive grains 22-1, 23-1 consist entirely of solder metal, in which case a metal selected from the group consisting of tin, indium, gallium or a soft-solder alloy can be used as solder metal. In this case, a solderable metal which may be a metal selected from the group consisting of copper, nickel, silver or gold is used as material for the pads 11, 21 of the electronic circuit system 10 and substrate 20. Also in this embodiment~~too~~, the electrically conductive grains 22-1, 23-1 of the microcapsules 22-1, 22-2, 23-1, 23-2 are surrounded by a dielectric 22-2, 23-2 in the form of a layer of insulating enamel. ~~As well as its insulating action in the lateral direction, which has been~~

~~explained above, this~~This layer of insulating enamel additionally prevents in particular electrically conductive grains 22-1 in the lateral spaces between pads 11, 21 of electronic circuit system 10 and substrate 20 from flowing together when heated during the soldering process and therefore prevents short circuits in the lateral direction.

[0024] ~~**[0043]**~~ Since the solder material of the electrically conductive grains 23-1, 23-2 of the microcapsules 22-1, 22-2, 23-1, 23-2 becomes liquid during the soldering process, and therefore the layer of insulating enamel breaks more easily, the pressure required to break open this layer between pads 11, 21 which face one another is not as high as in the first embodiment of microcapsules~~ which was explained above~~. When the solder material makes contact with the material of the pads 11, 21, the soldered joint is formed, and therefore electrical and mechanical contact is made.

[0025] ~~**[0044]**~~ Since the microcapsules 22-1, 22-2 in the lateral spaces between pads are not compressed, their layers of insulating enamel 22-2 remain intact. When using an adhesive 24, these microcapsules are held together either by ~~this~~the adhesive, or when embedded in a polymer film~~ in the sense explained above~~, and cannot flow out. Therefore, in this embodiment~~ too~~, the diffusion-soldering method explained above is particularly advantageous. The electrically conductive grains 22-1, 23-1 of the microcapsules 22-1, 22-2, 23-1, 23-2 may, for example, consist of tin and the pads 11, 21 of electronic circuit system 10 and substrate 20 may consist of copper or nickel. If the electrically conductive grains of the microcapsules have a diameter of less than 10 μm, the tin is completely transformed into the intermetallic phase 26, 28 when contact is made between the solder metal and the pad metal. In turn, an electromechanical connection with a melting point which is significantly higher than that of the solder metal, and

therefore excellent mechanical properties, such a high tensile strength and freedom from creep~~,~~ is formed.

~~**[0045]** Electrically conductive grains with a small diameter of the order of magnitude of 10 μm and preferably less than 10 μm are advantageous for a number of reasons.~~

~~**[0046]** Firstly, the thicker the electrically conductive grains, the longer the process of chemical transformation takes during the diffusion soldering. For example, with a diameter of 40 μm the reaction takes over half an hour. With diameters of less than 10 μm, the reaction time is of the order of magnitude of minutes.~~

~~**[0047]** Secondly, the pads 11, 21 have to be sufficiently thick to be able to provide sufficient metal for the transformation reaction. When using electrically conductive grains having the preferred diameters, there is relatively little solder metal available, so that correspondingly a small amount of pad metal needs to be available for complete transformation.~~

[0026] ~~**[0048]** Thirdly~~Electrically conductive grains with a small diameter of the order of magnitude of 10 μm and preferably less than 10 μm are advantageous for a number of reasons. First~~Firstly~~, the thicker the electrically conductive grains~~,~~ the longer the process of chemical transformation takes during the diffusion soldering. For example, with a diameter of ~~40~~ about 40 μm the reaction takes over half an hour. With diameters of less than ~~10 μm,~~about 10 μm the reaction time is of the order of magnitude of minutes. Second~~Secondly~~, the pads 11, 21 have to be sufficiently thick to be able to provide sufficient metal for the transformation reaction. When using electrically conductive grains having the preferred diameters~~,~~ there is relatively little solder metal available~~, so~~

~~that correspondingly a~~ so that a correspondingly small amount of pad metal needs to be available for complete transformation. Third, small diameters of the electrically conductive grains are of benefit to finely structured contacts~~,~~ which ~~is~~are advantageous in particular for integrated semiconductor circuits with a high level of integration. ~~Fourthly~~Fourth, the diameter of the electrically conductive grains determines the thickness of the soldered joint. Thin soldered joints have a better fracture behavior. With a thickness of less than about 5 µm~~,~~ the joint has ~~a~~an elastic action when bent, whereas if its thickness is greater than about 10 µm it becomes brittle, so that stress cracks may easily form.

[0027] ~~[0049] As~~In a modification ~~to~~of the embodiment described above, the electrically conductive grains 22-1, 22-2 of the microcapsules 22-1, 22-2, 23-1, 23-2 may not consist entirely of solder metal, but rather may consist of a metal core which is covered with solder metal. This may, for example, be a copper core which is covered with a layer of ~~tine~~tin solder. If the tin solder is deposited electrolessly in a tin exchange bath, the top layer of the copper core is replaced by a correspondingly thin layer of tin. A typical thickness of the layer of tin is of the order of magnitude of about 200 nm.

[0028] ~~[0050]~~ The use of electrically conductive grains of this type, including ~~for~~their use in the mechanical and electrical connection of objects, is ~~known per se, for example from~~disclosed in 1996 "Electronic Components and Technology Conference", pages 565-~~570,~~570 which describes an electrically conductive adhesive material which comprises a conductive filler powder~~,~~ which is covered with a metal with a low melting point (solder metal), a thermoplastic polymer, and further minor organic additives. The filler grains are coated with the metal of a low melting point which, when producing a connection

between objects, is melted in order to produce a metallurgical bond between adjacent filler grains and between filler grains and metallic connection elements on the objects which are to be connected. A connection of this type corresponds to the arrangement shown in ~~Fig.~~Figure 1. In this case, ~~too~~however, the problems explained above with regard to the adhesive formed by the polymer and with regard to the amount of electrically conductive grains used~~, are~~ may be encountered.

[0029] ~~[0051] As in~~In the two embodiments ~~explained~~discussed above, electrically conductive grains 22-1, 22--2~~ of this type~~ are covered with a dielectric 22-2, 23-2 in the form of a layer of insulating enamel. It should be noted that the fact that the electrically conductive grains may for their part be of two-part form is not specifically illustrated in Figures 2 to 4.

[0030] ~~[0052]~~ One advantage of electrically conductive grains 22-1, 23-1 in the form of metal cores which are covered with solder metal is that the soldering process, which is once again preferably in the form of the diffusion-soldering process, takes place very quickly and precisely~~,~~ on account of the overall very thin layer of solder. A further advantage is that even in microcapsules 22-1, 22-2 in the lateral spaces between pads 11, 21, which are therefore not in contact with pads 11, 21, the solder reacts with the core metal and is transformed into an intermetallic phase. Therefore, microcapsules of this type~~, too,~~ are firmly stable at temperatures which lie well above the melting point of the solder, since they can no longer become liquid.

[0031] ~~[0053]~~ Furthermore, on account of the low thickness of the layers of solder of the electrically conductive grains and the resultant relatively small quantity of solder metal,

the thickness of the pads 11, 21 can be reduced~~,~~ since a correspondingly small quantity of pad material is required for complete transformation of the quantity of solder. A further reason for using layers of solder of small thickness is that it is ~~no longer~~not necessary for the pads to be raised~~,~~ since the solder of the electrical conductive grains ~~can no longer~~cannot "run out" when the layer of insulating enamel breaks open~~,~~ since the low layer thickness means that the solder adheres to the surface of the metal core, providing good wetting of the latter. Accordingly~~For the above reasons~~, in all the microcapsules 22-1, 22-2, 23-1, 23-2, both those in lateral spaces between pads 11, 21 and those between pads which face one another, it is no longer possible for any liquid solder, which leads to short circuits, to form at operating temperatures of the arrangement. Hence electromechanical~~Electromechanical~~ contact with the pads 11, 21 results from the reaction of the solder of the electrically conductive grains 23-1, 23-2 with the metal of the pads 11, 21.

~~[0054] For the above reasons, in all the microcapsules 22-1, 22-2, 23-1, 23-2, both those in lateral spaces between pads 11, 21 and those between pads which face one another, it is no longer possible for any liquid solder, which leads to short circuits, to form at operating temperatures of the arrangement.~~

~~[0055] Electromechanical contact with the pads 11, 21 results from the reaction of the solder of the electrically conductive grains 23-1, 23-2 with the metal of the pads 11, 21.~~

[0032] ~~[0056]~~ A further advantage in ~~particular in~~ the embodiments with electrical conductive grains 22-1, 23-1 comprising metal other than solder metal and layers of solder 25, 27 on the pads 11, 21, as well as electrically conductive grains comprising

metal cores covered with a layer of solder, is that it is possible to produce particularly thin solder layers, which can be controlled accurately, during the diffusion-soldering method, in the form of intermetallic phases 26, 28.

[0033] ~~[0057]~~ In the embodiments described above, the microcapsules 22-1, 22-2, 23-1, 23-~~2,~~2 (apart from the variant involving the embedding in a polymer film~~,~~) can be processed with an insulating liquid~~,~~ which may be the above-mentioned adhesive 24 or a flux~~,~~ to form a paste. In the case of the adhesive~~,~~ it is possible to combine the advantages of an adhesive bond and of a soldered joint. This adhesive bond ensures additional mechanical stability, and the soldered joint ensures reliable electrical connection.

[0034] ~~[0058]~~ To summarize, ~~it should be pointed out once again that,~~ according to the present invention~~,~~ it is possible to achieve a creep-resistant connection, since during the preferred diffusion soldering the solder material~~,~~ (as a thin layer on the microcapsules or the connection elements on the electronic circuit system and the substrate~~,~~) is completely changed into the intermetallic phase, i.e. no residues of solder material remain. ~~Furthermore, the~~The thin layers of solder material ensure that the soldering process takes place relatively quickly. Furthermore, the large quantity of microcapsules which is possible even with small connection element structures means that reliable electrical connection in combination with good thermal conduction and ~~—on~~ (on account of the mechanical soldered joint via the soldered microcapsules~~—~~) a significantly more reliable mechanical connection compared to a pure adhesive bond is ensured. Finally, high thermal stability of electromechanical connection is also ~~ensured,~~ensured since the overall connection operation can be designed in such a way that no residues, such as for

example insulating residues of metal oxides, glass or ceramic or binder, remain in the connection.

~~**[0059]** Furthermore, the large quantity of microcapsules which is possible even with small connection element structures means that reliable electrical connection in combination with good thermal conduction and —~~ on ~~account of the mechanical soldered joint via the soldered microcapsules—a significantly more reliable mechanical connection compared to a pure adhesive bond is ensured.~~

~~**[0060]** Finally, high thermal stability of electromechanical connection is also~~ ensured, ~~since the overall connection operation can be designed in such a way that no residues, such as for example insulating residues of metal oxides, glass or ceramic or binder, remain in the connection.~~

~~I(WE)~~ CLAIM:

35. ~~1.~~ An electromechanical connection between electronic circuit systems ~~(10)~~ and substrates ~~(20)~~, ~~in which an~~comprising the electronic circuit system ~~(10)~~ and ~~a~~ substrate ~~(20) are~~ mechanically connected ~~fixedly~~ to one another, and electrical connection elements ~~(11, 21)~~ which face one another on the electronic circuit system ~~(10) and the substrate (20) are in each case~~ connected in an electrically conductive manner by means of microcapsules ~~(23-1, 23-2), and in which the microcapsules (23-1, 23-2) are~~ formed ~~by~~from grains ~~(23-1)~~ which are coated with a dielectric ~~(23-2)~~ and which are at least ~~in part are~~partially electrically conductive, ~~characterized in that~~wherein the dielectric ~~(23-2)~~ of the microcapsules ~~(23-1, 23-2)~~ is broken open at least on ~~its~~ areas which face the electrical connection elements ~~(11,~~to ~~21), and at the correspondingly~~provide exposed areas of the grains, ~~(23-1)~~and an electrically conductive soldered joint ~~(25 to 28)~~ is formed ~~in each case~~ between the exposed areas of the grains ~~(23-1)~~ and the electrically conductive connection elements ~~(11, 21), which in each case face these areas, of the electronic circuit system (10) and of the substrate (20), respectively~~.

36. ~~2.~~ The electromechanical connection ~~as claimed in~~according to claim ~~1, characterized in that~~35, wherein the ~~mechanically fixed~~mechanical connection between the electronic circuit system ~~(10)~~ and substrate ~~(20)~~ is made by means of an adhesive ~~(24)~~.

37. ~~3.~~ The electromechanical connection ~~as claimed in claims 1 and 2, characterized in that~~according to claim 36, wherein the adhesive ~~(24) used~~ is formed from a polymer.

38. ~~4.~~ The electromechanical connection ~~as claimed in one of claims 1 to 3, characterized in that~~according to claim 36, wherein the microcapsules ~~(23-1, 23-2)~~ are embedded in the adhesive ~~(24)~~.

39. ~~5.~~ The electromechanical connection ~~as claimed in~~according to claim ~~1, characterized in that~~35, wherein the ~~mechanically fixed~~mechanical connection between electronic circuit system ~~(10)~~ and substrate ~~(20)~~ is formed by a soldered joint between connection elements ~~(11, 21)~~ which are inactive in the intended electronic functioning of electronic circuit system ~~(10) and substrate (20)~~.

40. ~~6.~~ The electromechanical connection ~~as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains ~~(23-1) which are~~ selected from the group of metals consisting of copper, nickel, silver, and gold ~~and are covered with a dielectric (23-2) are used as microcapsules (23-1, 23-2)~~.

41. ~~7.~~ The electromechanical connection ~~as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains ~~(23-1)~~ of a solderable metal alloy~~, which are covered with a dielectric (23-2), are used as microcapsules (23-1, 23-2)~~.

42. ~~8.~~ The electromechanical connection ~~as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are metallized~~,~~ insulating grains ~~(23-1) which are covered with a dielectric (23-2) are used as microcapsules (23-1, 23-2)~~.

43. ~~9.~~ The electromechanical connection ~~as claimed in~~according to claim ~~8, characterized in that~~42, wherein the grains are silver-plated tin oxide grains ~~are used as metallized, insulating grains (23-1)~~.

44. ~~10.~~ The electromechanical connection ~~as claimed in one of claims 6 to 9, characterized in that~~according to claim 35, wherein the dielectric is an insulating enamel ~~is used as the dielectric (23-2) of the microcapsules (23-1, 23-2)~~.

45. ~~11.~~ The electromechanical connection ~~as claimed in claim 10, characterized in that a soldering flux is used as~~according to claim 44, wherein the insulating enamel is a soldering flux.

46. ~~12.~~ The electromechanical connection ~~as claimed in one of claims 1 to 11, characterized in that~~according to claim 35, wherein the electrically conductive soldered joint ~~(25 to 28)~~ between the connection elements ~~(11, 21) of electronic circuit system (10) and substrate (20)~~ is formed by ~~soldering of~~ layers of solder ~~(25, 27)~~ which are provided on the connection elements ~~(11, 21)~~ to form intermetallic phases ~~(26, 28)~~ comprising material of the electrically conductive grains ~~(23-1)~~ of the microcapsules ~~(23-1, 23-2)~~ and the layers of solder ~~(25, 27)~~.

47. ~~13.~~ The electromechanical connection ~~as claimed in~~according to claim ~~12, characterized in that~~46, wherein a metal selected from the group consisting of ~~ten~~tin, indium and gallium is used as the material for the layers of solders ~~(25, 27)~~.

48. ~~14.~~ The electromechanical connection ~~as claimed in~~according to claim ~~12, characterized in that~~46, wherein a metal alloy ~~with~~having a low melting point is used as the material for the layers of solder ~~(25, 27)~~.

49. ~~15.~~ The electromechanical connection ~~as claimed in~~according to claim ~~13 or 14, characterized in that~~47, wherein the layers of solder ~~(25, 27) are~~comprise layers of tin which have been deposited selectively ~~and~~ without ~~using~~the use of an electric current.

50. ~~16.~~ The electromechanical connection ~~as claimed in one of claims 1 to 15, characterized in that~~according to claim 35, wherein the electrical connection elements

comprise a metallic material which is matched to the metallic material of the conductive grains ~~(23-1) of the microcapsules (23-1, 23-2) is used as material for the connection elements (11, 21) of electronic circuit system (10) and substrate (20)~~.

51. ~~17.~~ The electromechanical connection ~~as claimed in claim 16, characterized in that~~according to claim 50, wherein ~~(23-1) of the microcapsules (23-1, 23-2) is used as material for~~ the connection elements ~~(11, 21) of electronic circuit system (10) and substrate (20)~~comprise a metal selected from the group consisting of copper ~~or~~and nickel ~~is used as material for the connection elements (11, 21)~~.

52. ~~18.~~ The electromechanical connection ~~as claimed in one of claims 1 to 17, characterized in that~~according to claim 35, wherein the microcapsules are provided in a single layer, ~~of~~said microcapsules ~~(23-1, 23-2)~~being of a uniform size and embedded in a polymer film ~~are provided~~.

53. ~~19.~~ The electromechanical connection ~~as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains ~~(23-1) which are~~ covered with an insulating enamel ~~(23-2) and~~, which grains at least in part consist of a solder metal ~~are used as microcapsules (23-1, 23-2)~~.

54. ~~20.~~ The electromechanical connection ~~as claimed in~~according to claim ~~19, characterized in that~~53, wherein the electrically conductive grain ~~(23-1)~~ of the microcapsules ~~(23-1, 23-2)~~ consist entirely of solder metal.

55. ~~21.~~ The electromechanical connection ~~as claimed in~~according to claim ~~19 or 20, characterized in that a~~53, wherein the solder metal is selected from the group consisting of tin, indium, and gallium ~~is used for the electrically conductive grains (23-1)~~.

56. ~~22.~~ The electromechanical connection ~~as claimed in claim 19 or 20, characterized in that~~according to claim 53, wherein the solder metal is a soft-solder alloy ~~is used for the electrically conductive grains (23-1)~~.

57. ~~23.~~ The electromechanical connection ~~as claimed in one of claims 19 to 22, characterized in that~~according to claim 53, wherein a solderable metal is used for the connection elements ~~(11, 21)~~ of electronic circuit system ~~(10) and substrate (20)~~.

58. ~~24.~~ The electromechanical connection ~~as claimed in~~according to claim ~~23, characterized in that a~~57, wherein the solderable metal is selected from the group consisting of copper, nickel, silver, and gold ~~is used as the solderable metal for the connection elements (11, 21)~~.

59. ~~25.~~ The electromechanical connection ~~as claimed in~~according to claim ~~19, characterized in that~~53, wherein the electrically conductive grains ~~(23-1)~~ of the microcapsules ~~(23-1, 23-2)~~ are formed from an electrically conductive metal core which is covered with a solder material.

60. ~~26.~~ The electromechanical connection ~~as claimed in claim 25, characterized in that~~according to claim 59, wherein the electrically conductive metal core is comprised of copper ~~is used as material for the electrically conductive metal core~~.

61. ~~27.~~ The electromechanical connection ~~as claimed in claim 25 and/or 26, characterized in that tin is used as solder material for~~according to claim 59, wherein the covering of the core is comprised of tin.

62. ~~28.~~ The electromechanical connection ~~as claimed in one of claims 1 to 27, characterized in that~~according to claim 35, wherein the electrically conductive grains ~~(23-1)~~ of the microcapsules ~~(23-1, 23-2)~~ have a diameter of ~~the order of magnitude of 10 µm, preferably less than~~about 10 µm.

63. ~~29.~~ The electromechanical connection ~~as claimed in~~according to claim ~~27, characterized in that~~61, wherein the tin covering of the core has a thickness of ~~the order of magnitude of~~about 200 nm.

64. ~~30.~~ The electromechanical connection ~~as claimed in one of claims 1 to 18, characterized in that~~according to claim 46, wherein the layers of solder which are applied to the connection elements ~~(11, 21)~~ have a thickness of ~~the order of magnitude of~~about 10 ~~μm, preferably less than 10~~ μm.

65. ~~31.~~ A method for producing the electromechanical connection ~~as claimed in one of claims 1 to 30, characterized in that, after~~according to claim 35, comprising compressing the microcapsules ~~(23-1, 23-2) embedded in an adhesive (24) or a polymer film have been introduced between electronic circuit system (10) and substrate (20), the microcapsules (23-1, 23-2) between the connection elements (11, 21) of the circuit system (10) and of the substrate (20) are compressed~~ under ~~such~~ a force such that the dielectric ~~(23-2)~~coating on ~~electrically conductive~~the grains ~~(23-1) situated between connection elements (11, 21) which face one another~~ is broken open, and producing the soldered joint ~~(25 to 28) in each case between those areas of the grains (23-1) which face the connections (11, 21) and the connections (11, 21) is produced~~ by diffusion soldering.

66. ~~32.~~ The method ~~as claimed in~~according to claim ~~31, characterized in that~~65, further comprising applying layers of solder metal ~~(25, 27) are applied~~ to connection elements ~~(11, 21)~~ in a thickness ~~which is~~ such that, during a diffusion-soldering process ~~between metals of the electrically conductive grains (23-1) or grains (23-1) in the form of metallized insulators and the solder metal~~, the solder metal is completely converted into an intermetallic phase ~~(26, 28)~~.

67. ~~33.~~ The method ~~as claimed in~~according to claim ~~31, characterized in that, when using~~65, wherein the microcapsules ~~(23-1, 23-2) whose~~have electrically conductive grains ~~(23-1) consist~~consisting entirely of solder metal, and connection elements ~~(11, 21)~~ which are free of solder metal ~~on electronic circuit system (10) and substrate (20)~~, ~~the~~further comprising selecting a thickness of the connection elements ~~(11, 21) is selected in such a way~~so that sufficient material is available for ~~the~~a transformation process during the diffusion soldering.

68. ~~34.~~ The method ~~as claimed in~~according to claim ~~31, characterized in that, when using~~65, wherein the microcapsules ~~(23-1, 23-2) whose~~have electrically conductive grains ~~(23-1) comprise~~comprising an electrically conductive metal core covered with a solder metal, and wherein the connection elements ~~(11, 21) which~~ are free of solder metal on electronic circuit system ~~(10)~~ and substrate ~~(20)~~, further comprising selecting the thickness of the connection elements ~~(11, 21)~~ and ~~of~~ the solder metal ~~is selected~~ in such a way that ~~their material~~there is sufficient material, during the diffusion soldering~~,~~ for ~~the~~a transformation process ~~between connection element material and core metal having the solder metal.~~.

69. The electromechnical connection according to claim 62, wherein the diameter of the microcapsules is less than 10 µm.

70. The electromechanical connection according to claim 64, wherein the layers of solder have a thickness of less than 10 µm.

ABSTRACT OF THE DISCLOSURE

In an electromechanical connection between electronic circuit systems (10) and substrates (20), these components are mechanically connected fixedly to one another, their electrical connection elements (11, 21) are connected to one another in an electrically conductive manner via microcapsules (23-1, 23-2), which comprise grains (23-1) which are coated with a dielectric (23-2) and, at least in part, are electrically conductive, and there is an electrically conductive soldered joint (25 to 28) between microcapsules (23-1, 23-2) with broken-open dielectric (23-2) and the electrical connection elements (11, 21).

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Description

Electromechanical connection between electronic circuit systems and substrates, and method for producing this connection

The present invention relates to an electromechanical connection between electronic circuit systems and substrates in accordance with the preamble of patent claim 1 and to a method for its production in accordance with patent claim 31.

In the context of the present invention, the term electronic circuit systems is understood as meaning solid-state circuit systems, in particular integrated semiconductor circuits. Specifically, the term system indicates, for example in an integrated semiconductor circuit, the semiconductor material body which holds the electronic functional circuit elements, such as transistors, diodes, capacitors, etc., and the metallic conductor tracks and connection elements which are situated on this body and connecting the functional circuit elements.

The connection elements may be flat applications of metal, known as pads, or spherical metallic elements, known as bumps.

In the context of the present invention, the term substrates is understood as meaning circuit boards, such as printed circuits or printed-circuit boards. Substrates of this type also have connection elements of the abovementioned type, generally in the form of pads.

It is known to produce electromechanical connections of

the type under discussion by means of an adhesive which

contains electrically conductive grains. An electro-mechanical connection of this type is explained below with reference to Fig. 1.

Fig. 1 diagrammatically depicts an electronic circuit system 10, for example an integrated semiconductor circuit, which is electrically and mechanically connected to a substrate 20, for example a printed-circuit board. Connection elements in the form of pads are present on the circuit system 10, and connection elements 21, which are likewise in the form of pads, are present on the substrate 20.

The circuit system 10 and the substrate 20 are connected to one another using the flip-chip technology in such a manner that the pads 11 and 21 come to lie facing one another, with an adhesive 24, which contains electrically conductive grains 22 and 23 and is indicated by dot-dashed lines, between them. The adhesive 24 may, for example, be a polymer, while the conductive grains may consist of silver.

In a connection of the abovementioned type, electrically conductive grains, which are in this case denoted by 22, come to lie in the lateral spaces between the pads 11 and 21, and conductive grains which are denoted by 23 come to lie in the vertical spaces between pads 11 and 21 which face one another.

Pressing the circuit system 10 and substrate 20 together ensures that the electrically conductive grains 23 between pads 11 and 21 which face one another come into electrically conductive contact with these pads, producing an electrical connection between circuit system 10 and substrate 20. By contrast, the electrically conductive grains 22 in the lateral spaces between pads 11 and 21 do not come into electrically conductive connection with the pads, so that in this respect there is no short-circuiting connection between pads. An

electrical connection of the type described is anisotropically conductive, in that an electrically

conductive connection is produced in the vertical direction by electrically conductive grains 22 between pads 11 and 21 which face one another, but is not produced in

the lateral direction by electrically conductive grains 22 in lateral spaces between pads 11 and 21.

To indicate that the electrically conductive grains 23 between pads 11 and 21 which face one another can be deformed during compression, they are diagrammatically indicated in an oval shape, while the grains 22 in the lateral spaces between pads 11 and 21 remain undeformed and are therefore diagrammatically indicated in the shape of a circle.

In the type of electromechanical connection described above, the following conditions have to be satisfied for reliable operation.

Firstly, the adhesive 24, during setting and when the circuit system 10 and substrate 20 are operating, has to develop sufficiently high shrinkage forces to ensure permanent compression and therefore a reliable mechanical connection between circuit system 10 and substrate 11. However, adhesives do not generally have good properties in terms of adhesion and resistance to moisture, and consequently a connection of this type is not sufficiently reliable. Particularly in the event of fluctuating thermal loads, high shear forces may arise in the adhesive join, with the result that the adhesive may break open and, as a result, the electrical connection through the electrically conductive grains 23 may be broken. Furthermore, moisture which penetrates into the join may, when heated, cause entire areas of the circuit system 10 to break away from the substrate 20. These drawbacks are offset by the advantage that adhesives do not need to be structured.

Secondly, the amount of electrically conductive grains

22, 23 in the adhesive 24 must be sufficiently large to

ensure that there is at least one electrically conductive grain 23 between pads 11, 21 which face one another, in order to guarantee an electrically conductive connection. On the other hand, the amount of these grains must not be so high that there is a risk of

electrical short circuits being caused by electrically conductive grains 22 in lateral spaces between pads 11, 21.

As the level of integration increases and therefore the electrically conductive structures become smaller, as do the distances between them on integrated semiconductor circuits and matching structures on substrates connected to the circuits, such as for example printed-circuit boards, the latter problem becomes increasingly important.

To counteract this problem, it is known from "Flip Chip Technologies" by John H. Lau, McGraw-Hill, 1996, pages 289-299, to use microcapsules which are embedded in an adhesive and comprise electrically conductive grains and a dielectric surrounding them, for example in the form of an insulating plastic. A microcapsule of this type comprising an electrically conductive grain 22-1 (or 23-1) and a dielectric 22-2 (or 23-2) surrounding it is illustrated on an enlarged scale in Fig. 2.

In an electromechanical connection using conductive grains surrounded by a dielectric in an adhesive also requires the circuit system 10 and the substrate 20 to be pressed together, as shown in Fig. 1. As a result of the pressure which is generated by this operation and the setting of the adhesive 24, the microcapsules 23-1, 23-2 between pads 11, 21 which face one another are compressed, with the result that the dielectric 23-2 is broken open and, as a result, an electrically conductive connection is formed via the electrically conductive grains 23-1. This state of affairs is diagrammatically illustrated in Fig. 3 in the form of a deformed microcapsule 23-1, 23-2 between two pads 11, 21.

Although in an electromechanical connection of this type produced by means of microcapsules of the type described above the problem of lateral electric short circuits via microcapsules 22-1, 22-2 situated in the lateral spaces between pads 11, 21 is virtually eliminated,

the problems described above in connection with the adhesive remain as before.

The present invention is based on the object of providing an electromechanical connection of the type under discussion which, even with fine electrically conductive structures on electronic circuit systems and substrates, is both mechanically and electrically stable and prevents electric short circuits.

With an electromechanical connection of the generic type, this object is achieved, according to the invention, by the measures given in the characterizing part of patent claim 1.

A method for producing an electromechanical connection according to the invention is characterized by the measures given in patent claim 31.

Refinements of the electromechanical connection according to the invention and of the method according to the invention form the subject matter of corresponding subclaims.

The invention is explained in more detail below on the basis of exemplary embodiments in conjunction with the figures of the drawing, in which:

Figures 1 to 3 show the known embodiments which have already been explained above, and

Fig. 4 shows a diagrammatic illustration, corresponding to that shown in Fig. 1, of an electromechanical connection in order to explain embodiments in accordance with the invention.

The essence of the invention is to be seen as residing in the fact that, in addition to a compressive connection to produce the electrical connection between an electronic circuit system and a

substrate, a metallic solder joint is produced at least at the locations of the electrical connections.

In Fig. 4, on the basis of which embodiments of the invention are explained, identical elements to those shown in Figures 1 to 3 are provided with identical reference symbols.

As has already been explained with reference to Fig. 1, the arrangement shown in Fig. 4 is likewise an electro-mechanical connection between an electronic circuit system 10, for example an integrated semiconductor circuit system, and a substrate 20, for example an electrical printed-circuit board. Electronic circuit system 10 and substrate 20 once again have the connection elements in the form of pads 11 and 21.

The purely mechanical connection takes place by means of the adhesive 24 which is indicated by dot-dashed lines, for example a polymer, in which, however, unlike in the known embodiment shown in Fig. 1, it is not purely metallic electrically conductive particles 22, 23, but rather microcapsules 22-1, 22-2, 23-1, 23-2 which are suitable for a soldering operation that are embedded. Embodiments of these microcapsules are explained in more detail below.

It should be noted that the invention is not restricted to embodiments used with an adhesive 24 to produce the purely mechanical connection between electronic circuit system 10 and substrate 20. Embodiments in which a connection is produced by means of a soldering operation without adhesive, which is described in even more detail below, are also possible. This can take place by means of pads 11, 21 which are inactive for the intended

"inactivity" means that pads of this type are not electrically connected to electronic functional elements in electronic circuit system 10 or on or in substrate 20.

electronic operation of electric circuit system 10 and substrate. In this context, the term

A first embodiment of a soldered joint in the context of the invention is explained below.

In this embodiment, the microcapsules comprise electrically conductive grains 22-1, 23-1 which are covered with a dielectric 22-2, 23-2 and may consist of a metal selected from the group consisting of copper, nickel, silver, gold, a solderable metal alloy or an insulator, for example tin oxide, which is covered with an electrically conductive metal, for example silver. The way in which microcapsules of the latter type can be produced is known, for example, from "JOURNAL OF MATERIALS SCIENCE" 28 (1993), pages 5207-5210.

The dielectric 22-2, 23-2 used may be an insulating enamel, which may also act as a soldering flux.

For the soldering operation, layers of solder 25, 27, for which a metal selected from the group consisting of tin, indium, gallium, or a metal alloy with a low melting point may be used, are provided on the pads 11, 21 in order to produce the electrically conductive connection between electronic circuit system 10 and substrate 20. The layers of solder 25, 27 are preferably produced by selective electroless deposition on the pad surfaces, so that it is possible to produce sufficiently planar surfaces.

In accordance with the method according to the invention, microcapsules 22-1, 22-2, 23-1, 23-2, which are embedded in the adhesive 24 or a polymer film, which is not specifically shown in Fig. 4, are introduced between the electronic circuit system 10 and the substrate 20, and they are compressed together under such a force that the dielectric 23-2 of microcapsules 23-1, 23-2 situated

which face one another is broken open. After the compression, the arrangement is heated to a temperature which lies above the melting point of the solder material of the layers of solder 25, 27. In the process, the molten solder comes into contact with material of the electrically conductive grains 23-1 of the

between pads 11, 21

microcapsules 23-1, 23-2, and a metallic bond with good electrical conductivity is produced.

Microcapsules 22-1, 22—2 in lateral spaces between pads 11, 21 remain unaffected by the compression operation and therefore their dielectric 22-2 remains intact, with the result that lateral short circuits are prevented. Therefore, the electromechanical connection according to the invention is anisotropically conductive in the sense explained above.

It is particularly advantageous if a diffusion-soldering method is used for the soldering. In this method, a metallic bond which is able to withstand high temperature is produced using a low-melting solder as a result of the solder metal forming an intermetallic phase, which is able to withstand high temperatures and is very mechanically stable, with high-melting metals which are to be connected. In the process, the low-melting solder metal is completely transformed, i.e. passes completely into the intermetallic phase. A soldering method of this type is known per se, for example from US-A 5 053 195.

For this method, the layers of solder 25, 27 have a thickness of the order of magnitude of 10 μm, preferably of less than 10 μm. They consist, for example, of tin. The electrically conductive grains 23-1 or the metallic layers of grains in the form of metallized insulators, and if appropriate the pads 11, 21, consist, for example, of copper or nickel. When contact is made between the metal of the grains during the diffusion-soldering method, the tin is completely transformed into intermetallic phases, which are denoted by 26, 28 in Fig. 4. As has already been explained, the joint which is formed in the process has a significantly higher melting

metal and better mechanical properties, such as high tensile strength and freedom from creep.

In a development of the invention, it is essential in a soldering process of this type that a single

point than the solder

layer of microcapsules is situated between the pads 11, 21 and the pad surfaces are sufficiently planar. Then, all the microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another are compressed, so that their electrically conductive grains 23-2 or their electrically conductive parts come into contact with the solder metal.

The single-layer structure can be produced particularly successfully if – as stated above – the microcapsules 22-1, 22-2, 23-1, 23-2 are previously embedded in a polymer film. The way in which films with embedded microcapsules of this type can be built up and produced in detail is known per se, for example from 1992 "IEEE", pages 473 to 480 and 487 to 491. A film of this type ensures the lateral insulation of the microcapsules 22-1, 22-2, 23-1, 23-2 and can act as a spacer. Shaped parts which match the surfaces which are to be connected can be produced. The adhesive 24 can then be dispensed with, if appropriate.

It should be mentioned once again that the configuration described above is not specifically illustrated in Fig. 4. Also, soldered joints between pads 11, 21 which are inactive in the sense mentioned above and microcapsules 23-1, 23-2 without any adhesive 24 being present are not specifically illustrated in Fig. 4. However, in Fig. 4 it would be possible, for example, for the two pads 11, 21 shown on the right-hand side of the drawing to be regarded as "inactive" pads and for the two pads 11, 21 situated on the left-hand side of the drawing to be regarded as "active" pads.

In a further embodiment of the invention, it is possible to use microcapsules 22-1, 22-2, 23-1, 23-2 which at

least in part consist of a solder metal.

According to one variant of this embodiment, the electrically conductive grains 22-1, 23-1 consist entirely of solder metal, in which case a metal selected from the group consisting of tin, indium, gallium or a soft-solder alloy can be used as solder metal.

In this case, a solderable metal which may be a metal selected from the group consisting of copper, nickel, silver or gold is used as material for the pads 11, 21 of the electronic circuit system 10 and substrate 20.

In this embodiment too, the electrically conductive grains 22-1, 23-1 of the microcapsules 22-1, 22-2, 23-1, 23-2 are surrounded by a dielectric 22-2, 23-2 in the form of a layer of insulating enamel. As well as its insulating action in the lateral direction, which has been explained above, this layer of insulating enamel additionally prevents in particular electrically conductive grains 22-1 in the lateral spaces between pads 11, 21 of electronic circuit system 10 and substrate 20 from flowing together when heated during the soldering process and therefore prevents short circuits in the lateral direction.

Since the solder material of the electrically conductive grains 23-1, 23-2 of the microcapsules 22-1, 22-2, 23-1, 23-2 becomes liquid during the soldering process, and therefore the layer of insulating enamel breaks more easily, the pressure required to break open this layer between pads 11, 21 which face one another is not as high as in the first embodiment of microcapsules which was explained above. When the solder material makes contact with the material of the pads 11, 21, the soldered joint is formed, and therefore electrical and mechanical contact is made.

Since the microcapsules 22-1, 22-2 in the lateral spaces between pads are not compressed, their layers of insulating enamel 22-2 remain intact. When using an adhesive 24, these microcapsules are held together by this adhesive or when embedded in a polymer film in the

sense explained above, and cannot flow out.

Therefore, in this embodiment too, the diffusion-soldering method explained above is particularly advantageous. The electrically conductive grains 22-1, 23-1 of the microcapsules

22-1, 22-2, 23-1, 23-2 may, for example, consist of tin and the pads 11, 21 of electronic circuit system 10 and substrate 20 may consist of copper or nickel. If the electrically conductive grains of the microcapsules have a diameter of less than 10 μm, the tin is completely transformed into the intermetallic phase 26, 28 when contact is made between the solder metal and the pad metal. In turn, an electromechanical connection with a melting point which is significantly higher than that of the solder metal and therefore excellent mechanical properties, such a high tensile strength and freedom from creep, is formed.

Electrically conductive grains with a small diameter of the order of magnitude of 10 μm and preferably less than 10 μm are advantageous for a number of reasons.

Firstly, the thicker the electrically conductive grains, the longer the process of chemical transformation takes during the diffusion soldering. For example, with a diameter of 40 μm the reaction takes over half an hour. With diameters of less than 10 μm, the reaction time is of the order of magnitude of minutes.

Secondly, the pads 11, 21 have to be sufficiently thick to be able to provide sufficient metal for the transformation reaction. When using electrically conductive grains having the preferred diameters, there is relatively little solder metal available, so that correspondingly a small amount of pad metal needs to be available for complete transformation.

Thirdly, small diameters of the electrically conductive grains are of benefit to finely structured contacts, which is advantageous in particular for integrated

semiconductor circuits with a high level of integration.

Fourthly, the diameter of the electrically conductive grains determines the thickness of the soldered joint. Thin soldered joints have a better

fracture behavior. With a thickness of less than 5 μm, the joint has a elastic action when bent, whereas if its thickness is greater than 10 μm it becomes brittle, so that stress cracks may easily form.

As a modification to the embodiment described above, the electrically conductive grains 22-1, 22-2 of the microcapsules 22-1, 22-2, 23-1, 23-2 may not consist entirely of solder metal, but rather may consist of a metal core which is covered with solder metal. This may, for example, be a copper core which is covered with a layer of tine solder. If the tin solder is deposited electrolessly in a tin exchange bath, the top layer of the copper core is replaced by a correspondingly thin layer of tin. A typical thickness of the layer of tin is of the order of magnitude of 200 nm.

The use of electrically conductive grains of this type, including for use in the mechanical and electrical connection of objects, is known per se, for example from 1996 "Electronic Components and Technology Conference", pages 565-570, which describes an electrically conductive adhesive material which comprises a conductive filler powder, which is covered with a metal with a low melting point (solder metal), a thermoplastic polymer and further minor organic additives. The filler grains are coated with the metal of a low melting point which, when producing a connection between objects, is melted in order to produce a metallurgical bond between adjacent filler grains and between filler grains and metallic connection elements on the objects which are to be connected. A connection of this type corresponds to the arrangement shown in Fig. 1. In this case too, the problems explained above with regard to the adhesive formed by the polymer and with regard to the amount of

electrically conductive grains used, are encountered.

As in the two embodiments explained above, electrically conductive grains 22-1, 22-2 of this type are covered with a dielectric 22-2, 23-2 in the form of a layer of insulating enamel. It should be noted that the fact that the electrically conductive grains may for their part be of two-part form is not specifically illustrated in Figures 2 to 4.

One advantage of electrically conductive grains 22-1, 23-1 in the form of metal cores which are covered with solder metal is that the soldering process, which is once again preferably in the form of the diffusion-soldering process, takes place very quickly and precisely, on account of the overall very thin layer of solder. A further advantage is that even in microcapsules 22-1, 22-2 in the lateral spaces between pads 11, 21, which are therefore not in contact with pads 11, 21, the solder reacts with the core metal and is transformed into an intermetallic phase. Therefore, microcapsules of this type, too, are firmly stable at temperatures which lie well above the melting point of the solder, since they can no longer become liquid.

Furthermore, on account of the low thickness of the layers of solder of the electrically conductive grains and the resultant relatively small quantity of solder metal, the thickness of the pads 11, 21 can be reduced, since a correspondingly small quantity of pad material is required for complete transformation of the quantity of solder. A further reason for using layers of solder of small thickness is that it is no longer necessary for pads to be raised, since the solder of the electrical conductive grains can no longer "run out" when the layer of insulating enamel breaks open, since the low layer thickness means that the solder adheres to the surface of

the metal core, providing good wetting of the latter.

For the above reasons, in all the microcapsules 22-1, 22-2, 23-1, 23-2, both those in lateral spaces between pads 11, 21 and those between pads which face one another, it is no longer possible for any liquid solder, which leads to short circuits, to form at operating temperatures of the arrangement.

Electromechanical contact with the pads 11, 21 results from the reaction of the solder of the electrically conductive grains 23-1, 23-2 with the metal of the pads 11, 21.

A further advantage in particular in the embodiments with electrical conductive grains 22-1, 23-1 comprising metal other than solder metal and layers of solder 25, 27 on the pads 11, 21, as well as electrically conductive grains comprising metal cores covered with a layer of solder, is that it is possible to produce particularly thin solder layers, which can be controlled accurately, during the diffusion-soldering method, in the form of intermetallic phases 26, 28.

In the embodiments described above, the microcapsules 22-1, 22-2, 23-1, 23-2, apart from the variant involving embedding in a polymer film, can be processed with an insulating liquid, which may be the abovementioned adhesive 24 or a flux, to form a paste. In the case of the adhesive, it is possible to combine the advantages of an adhesive bond and of a soldered joint. This adhesive bond ensures additional mechanical stability, and the soldered joint ensures reliable electrical connection.

To summarize, it should be pointed out once again that, according to the invention, it is possible to achieve a creep-resistant connection, since during the preferred diffusion soldering the solder material, as a thin layer on the microcapsules or the connection elements on the electronic circuit system and the substrate, is completely changed into the intermetallic phase, i.e. no residues of solder material remain. Furthermore, the thin layers of solder material ensure that the soldering process takes place relatively quickly.

Furthermore, the large quantity of microcapsules which is possible even with small connection element structures means that reliable electrical connection in combination with good thermal conduction and - on account of the mechanical soldered joint via the soldered microcapsules - a significantly more reliable mechanical connection compared to a pure adhesive bond is ensured.

Finally, high thermal stability of electromechanical connection is also ensured, since the overall connection operation can be designed in such a way that no residues, such as for example insulating residues of metal oxides, glass or ceramic or binder, remain in the connection.

Patent Claims

1. An electromechanical connection between electronic circuit systems (10) and substrates (20), in which an electronic circuit system (10) and a substrate (20) are mechanically connected fixedly to one another, electrical connection elements (11, 21) which face one another on the electronic circuit system (10) and the substrate (20) are in each case connected in an electrically conductive manner by means of microcapsules (23-1, 23-2), and in which the microcapsules (23-1, 23-2) are formed by grains (23-1) which are coated with a dielectric (23-2) and at least in part are electrically conductive, characterized in that the dielectric (23-2) of the microcapsules (23-1, 23-2) is broken open at least on its areas which face the electrical connection elements (11, 21), and at the correspondingly exposed areas of the grains (23-1) an electrically conductive soldered joint (25 to 28) is formed in each case between the exposed areas of the grains (23-1) and the electrically conductive connection elements (11, 21), which in each case face these areas, of the electronic circuit system (10) and of the substrate (20), respectively.

2. The electromechanical connection as claimed in claim 1, characterized in that the mechanically fixed connection between the electronic circuit system (10) and substrate (20) is made by means of an adhesive (24).

3. The electromechanical connection as claimed in claims 1 and 2, characterized in that the adhesive

(24) used is a polymer.

4. The electromechanical connection as claimed in one of claims 1 to 3, characterized in that the micro-capsules (23-1, 23-2) are embedded in the adhesive (24).

5. The electromechnical connection as claimed in claim 1,

characterized in that the mechanically fixed connection between electronic circuit system (10) and substrate (20) is formed by a soldered joint between connection elements (11, 21) which are inactive in the intended electronic functioning of electronic circuit system (10) and substrate (20).

6. The electromechanical connection as claimed in one of claims 1 to 5, characterized in that electrically conductive metal grains (23-1) which are selected from the group of metals consisting of copper, nickel, silver, gold and are covered with a dielectric (23-2) are used as microcapsules (23-1, 23-2).

7. The electromechanical connection as claimed in one of claims 1 to 5, characterized in that electrically conductive metal grains (23-1) of a solderable metal alloy, which are covered with a dielectric (23-2), are used as microcapsules (23-1, 23-2).

8. The electromechanical connection as claimed in one of claims 1 to 5, characterized in that metallized, insulating grains (23-1) which are covered with a dielectric (23-2) are used as microcapsules (23-1, 23-2).

9. The electromechanical connection as claimed in claim 8, characterized in that silver-plated tin oxide grains are used as metallized, insulating grains (23-1).

10. The electromechanical connection as claimed in one of claims 6 to 9, characterized in that an insulating enamel is used as the dielectric (23-2)

of the microcapsules (23-1, 23-2).

11. The electromechanical connection as claimed in claim 10,

characterized in that a soldering flux is used as the insulating enamel.

12. The electromechanical connection as claimed in one of claims 1 to 11, characterized in that the electrically conductive soldered joint (25 to 28) between connection elements (11, 21) of electronic circuit system (10) and substrate (20) is formed by soldering of layers of solder (25, 27) which are provided on the connection elements (11, 21) to form intermetallic phases (26, 28) comprising material of the electrically conductive grains (23-1) of the microcapsules (23-1, 23-2) and the layers of solder (25, 27).

13. The electromechanical connection as claimed in claim 12, characterized in that a metal selected from the group consisting of ten, indium and gallium is used as the material for the layers of solders (25, 27).

14. The electromechanical connection as claimed in claim 12, characterized in that a metal alloy with a low melting point is used as the material for the layers of solder (25, 27).

15. The electromechanical connection as claimed in claim 13 or 14, characterized in that the layers of solder (25, 27) are layers of tin which have been deposited selectively and without using electric current.

16. The electromechanical connection as claimed in one of claims 1 to 15, characterized in that a metallic material which is matched to the metallic material of the conductive grains (23-1) of the microcapsules (23-1, 23-2) is used as material for

the connection elements (11, 21) of electronic circuit system (10) and substrate (20).

17. The electromechanical connection as claimed in claim 16,

characterized in that copper or nickel is used as material for the connection elements (11, 21).

18. The electromechanical connection as claimed in one of claims 1 to 17, characterized in that a single layer of microcapsules (23-1, 23-2) of uniform size embedded in a polymer film are provided.

19. The electromechanical connection as claimed in one of claims 1 to 5, characterized in that electrically conductive metal grains (23-1) which are covered with an insulating enamel (23-2) and at least in part consist of a solder metal are used as microcapsules (23-1, 23-2).

20. The electromechanical connection as claimed in claim 19, characterized in that the electrically conductive grain (23-1) of the microcapsules (23-1, 23-2) consist entirely of solder metal.

21. The electromechanical connection as claimed in claim 19 or 20, characterized in that a solder metal selected from the group consisting of tin, indium, gallium is used for the electrically conductive grains (23-1).

22. The electromechanical connection as claimed in claim 19 or 20, characterized in that a soft-solder alloy is used for the electrically conductive grains (23-1).

23. The electromechanical connection as claimed in one of claims 19 to 22, characterized in that a solderable metal is used for the connection elements (11, 21) of electronic circuit system (10) and

substrate (20).

24. The electromechanical connection as claimed in claim 23, characterized in that a metal selected from the group consisting of copper, nickel, silver, gold is used as the solderable metal for the connection elements (11, 21).

25. The electromechanical connection as claimed in claim 19, characterized in that the electrically conductive grains (23-1) of the microcapsules (23-1, 23-2) are formed from an electrically conductive metal core which is covered with a solder material.

26. The electromechanical connection as claimed in claim 25, characterized in that copper is used as material for the electrically conductive metal core.

27. The electromechanical connection as claimed in claim 25 and/or 26, characterized in that tin is used as solder material for the covering of the core.

28. The electromechanical connection as claimed in one of claims 1 to 27, characterized in that the electrically conductive grains (23-1) of the microcapsules (23-1, 23-2) have a diameter of the order of magnitude of 10 μm, preferably less than 10 μm.

29. The electromechanical connection as claimed in claim 27, characterized in that the tin covering of the core has a thickness of the order of magnitude of 200 nm.

30. The electromechanical connection as claimed in one of claims 1 to 18, characterized in that the

layers of solder which are applied to the connection elements (11, 21) have a thickness of the order of magnitude of 10 μm, preferably less than 10 μm.

31. A method for producing the electromechanical connection as claimed in one of claims 1 to 30, characterized in that, after microcapsules (23-1, 23-2) embedded in an adhesive (24) or a polymer film have been introduced between electronic circuit system (10) and substrate (20), the microcapsules (23-1, 23-2) between the connection elements (11, 21) of the circuit system (10) and of the substrate (20) are compressed under such a force that the dielectric (23-2) on electrically conductive grains (23-1) situated between connection elements (11, 21) which face one another is broken open, and the soldered joint (25 to 28) in each case between those areas of the grains (23-1) which face the connections (11, 21) and the connections (11, 21) is produced by diffusion soldering.

32. The method as claimed in claim 31, characterized in that layers of solder metal (25, 27) are applied to connection elements (11, 21) in a thickness which is such that, during a diffusion-soldering process between metals of the electrically conductive grains (23-1) or grains (23-1) in the form of metallized insulators and the solder metal, the solder metal is completely converted into an intermetallic phase (26, 28).

33. The method as claimed in claim 31, characterized in that, when using microcapsules (23-1, 23-2) whose electrically conductive grains (23-1) consist entirely of solder metal, and connection elements (11, 21) which are free of solder metal on electronic circuit system (10) and substrate (20),

the thickness of the connection elements (11, 21) is selected in such a way that sufficient

material is available for the transformation process during the diffusion soldering.

34. The method as claimed in claim 31, characterized in that, when using microcapsules (23-1, 23-2) whose electrically conductive grains (23-1) comprise an electrically conductive metal core covered with a solder metal, and connection elements (11, 21) which are free of solder metal on electronic circuit system (10) and substrate (20), the thickness of the connection elements (11, 21) and of the solder metal

Abstract

Electromechanical connection between electronic switching systems and substrates, and method for producing this connection

In an electromechanical connection between electronic circuit systems (10) and substrates (20), these components are mechanically connected fixedly to one another, their electrical connection elements (11, 21) are connected to one another in an electrically conductive manner via microcapsules (23-1, 23-2), which comprise grains (23-1) which are coated with a dielectric (23-2) and, at least in part, are electrically conductive, and there is an electrically conductive soldered joint (25 to 28) between microcapsules (23-1, 23-2) with broken-open dielectric (23-2) and the electrical connection elements (11, 21).

Figure 4

BAKER BOTTS L.L.P.

30 ROCKEFELLER PLAZA

NEW YORK, NEW YORK 10112

TO ALL WHOM IT MAY CONCERN:

Be it known that WE, Holger Huebner and Vaidyanathan Kripesh, citizens of Germany and India respectively, residing in Germany and India respectively, whose post office addresses are Hamsterweg 10, 85598 Baldham, Germany; and L-5/E Sarvamangala Colon, Ind-Chennai 600083, Ashok Nagar, India, respectively, have invented an improvement in:

ELECTROMECHANICAL CONNECTION BETWEEN ELECTRONIC CIRCUIT SYSTEMS AND SUBSTRATES, AND METHOD FOR PRODUCING THIS CONNECTION

of which the following is a

SUBSTITUTE SPECIFICATION

FIELD OF THE INVENTION

[0001] The present invention relates to an electromechanical connection between electronic circuit systems and substrates and to a method for its production.

BACKGROUND OF THE INVENTION

[0002] In the context of the present invention the term electronic circuit systems is understood as meaning solid-state circuit systems, in particular integrated semiconductor circuits. Specifically, the term system indicates, for example in an integrated semiconductor circuit, the semiconductor material body which holds the electronic functional circuit elements, such as transistors, diodes, capacitors, etc., and the metallic

conductor tracks and connection elements which are situated on this body and connecting the functional circuit elements. The connection elements may be flat applications of metal, known as pads, or spherical metallic elements, known as bumps. Further, in the context of the present invention, the term substrates is understood as meaning circuit boards, such as printed circuits or printed-circuit boards. Substrates of this type also have connection elements of the above-mentioned type, generally in the form of pads.

[0003] It is known to produce electromechanical connections of the type under discussion by means of an adhesive which contains electrically conductive grains. An electromechanical connection of this type is described below with reference to Figure 1, which diagrammatically depicts an electronic circuit system 10, e.g., an integrated semiconductor circuit, which is electrically and mechanically connected to a substrate 20, such as a printed-circuit board. Connection elements in the form of pads are present on the circuit system 10, and connection elements 21 which are also in the form of pads are present on the substrate 20. The circuit system 10 and the substrate 20 are connected to one another using the Flip-Chip Technology in such a manner that the pads 11 and 21 come to lie facing one another, with an adhesive 24, which contains electrically conductive grains 22 and 23 and is indicated by dot-dashed lines between them. The adhesive 24 may be a polymer, and the conductive grains may consist of silver.

[0004] In a connection of the above-mentioned type, the electrically conductive grains come to lie in the lateral spaces between the pads 11 and 21, and conductive grains by 23 come to lie in the vertical spaces between pads 11 and 21 which face one another. Pressing the circuit system 10 and substrate 20 together ensures that the electrically conductive grains 23 between pads 11 and 21 which face one another come into

electrically conductive contact with these pads, thus producing an electrical connection between circuit system 10 and substrate 20. The electrically conductive grains 22 in the lateral spaces between pads 11 and 21 do not come into electrically conductive connection with the pads, hence there is no short-circuiting connection between pads. An electrical connection of the type described is anisotropically conductive in that an electrically conductive connection is produced in the vertical direction by electrically conductive grains 23 between pads 11 and 21 which face one another, but is not produced in the lateral direction by electrically conductive grains 22 in lateral spaces between pads 11 and 21.

[0005] To indicate that the electrically conductive grains 23 between pads 11 and 21 which face one another can be deformed during compression, they are diagrammatically indicated in an oval shape. The grains 22 in the lateral spaces between pads 11 and 21 remain undeformed and are therefore diagrammatically indicated in the shape of a circle.

[0006] In the type of electromechanical connection described above, certain conditions have to be satisfied for reliable operation. First, during setting and while the circuit system 10 and substrate 20 are operating, the adhesive 24 has to develop sufficiently high shrinkage forces to ensure permanent compression, in order to provide a reliable mechanical connection between circuit system 10 and substrate 11. However, adhesives do not generally have good properties in terms of adhesion and resistance to moisture, and consequently a connection of this type is not sufficiently reliable. Particularly in the event of fluctuating thermal loads, high shear forces may arise in the adhesive joint, with the result that the adhesive may break open and the electrical connection through the electrically conductive grains 23 may be broken. Furthermore, moisture which may

penetrate into the joint, when heated, may cause entire areas of the circuit system 10 to break away from the substrate 20. These drawbacks may be offset by adhesives that do not need to be structured.

[0007] Second, the amount of electrically conductive grains 22, 23 in the adhesive 24 must be sufficiently large to ensure that there is at least one electrically conductive grain 23 between pads 11, 21 which face one another, in order to guarantee an electrically conductive connection. On the other hand, the amount of these grains must not be so high that there is a risk of electrical short circuits being caused by electrically conductive grains 22 in lateral spaces between pads 11, 21. This problem assumes greater importance as the level of integration increases and the electrically conductive structures become smaller, as do the distances between them on integrated semiconductor circuits and matching structures on substrates connected to the circuits, such as for example printed-circuit boards.

[0008] To counteract this problem, it is known from "Flip Chip Technologies" by John H. Lau, McGraw-Hill, 1996, pages 289-299, to use microcapsules which are embedded in an adhesive and comprise electrically conductive grains and a dielectric surrounding them, for example in the form of an insulating plastic. A microcapsule of this type comprising an electrically conductive grain 22-1 (or 23-1) and a dielectric 22-2 (or 23-2) surrounding it is illustrated on an enlarged scale in Figure 2.

[0009] In an electromechanical connection using conductive grains surrounded by a dielectric in an adhesive also requires the circuit system 10 and the substrate 20 to be pressed together, as shown in Figure 1. As a result of the pressure which is generated by

this operation and the setting of the adhesive 24, the microcapsules 23-1, 23-2 between pads 11, 21 which face one another are compressed. This results in the dielectric 23-2 being broken open and an electrically conductive connection is formed via the electrically conductive grains 23-1. This state of affairs is illustrated in Figure 3 in the form of a deformed microcapsule 23-1, 23-2 between two pads 11, 21. Although in an electromechanical connection of the type produced by means of microcapsules described above the problem of lateral electric short circuits via microcapsules 22-1, 22-2 situated in the lateral spaces between pads 11, 21 is virtually eliminated, the problems described above in connection with the adhesive remain as before.

SUMMARY OF THE INVENTION

[0010] The present invention provides an electromechanical connection which is both mechanically and electrically stable and prevents electric short circuits even with fine electrically conductive structures on electronic circuit systems and substrates. Specifically, an electromechanical connection is formed between electronic circuit systems and substrates which are mechanically connected. The electrical connection elements which face one another on the electronic circuit system and substrate are connected in an electronically conductive manner by means of microcapsules which are in the form of grains coated with a dielectric which is broken open on its areas which face the electrical connection elements. At the exposed areas of the grains an electrically conductive soldered joint is formed between the exposed areas of the grains and the electrically conductive connection elements which face these areas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention is described in greater detail below in connection with the drawings, in which:

Figures 1 to 3 illustrate known features of the invention which have been described hereinabove; and

Figure 4 illustrates an electromechanical connection corresponding to that shown in Figure 1 but which embodiment is in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0012] In accordance with the present invention, a metallic solder joint is produced at least at the locations of the electrical connections, in addition to a compressive connection to produce the electrical connection between an electronic circuit system and a substrate.

[0013] In Figure 4, identical elements to those shown in Figures 1 to 3 are provided with identical reference symbols. As explained in connection with Figure 1, Figure 4 illustrates an electromechanical connection between an electronic circuit system 10 (for example an integrated semiconductor circuit system), and a substrate 20 (for example an electrical printed-circuit board). Electronic circuit system 10 and substrate 20 also have the connection elements in the form of pads 11 and 21.

[0014] A purely mechanical connection occurs by means of the adhesive 24 which is indicated by dot-dashed lines, for example a polymer. However, unlike the known embodiment shown in Figure 1, it is not purely metallic electrically conductive particles 22, 23, but rather microcapsules 22-1, 22-2, 23-1, 23-2 which are suitable for a soldering

operation that are embedded. Embodiments of these microcapsules are explained in more detail below.

[0015] It should be noted that the invention is not restricted to embodiments used with an adhesive 24 to produce the purely mechanical connection between electronic circuit system 10 and substrate 20. Embodiments in which a connection is produced by means of a soldering operation without adhesive, which is described in even more detail below, are also possible. This can take place by means of pads 11, 21 which are inactive for the intended electronic operation of electric circuit system 10 and substrate. In this context, the term "inactivity" means that pads of this type are not electrically connected to electronic functional elements in electronic circuit system 10 or on or in substrate 20.

[0016] In one embodiment of a soldered joint in the context of the present invention, the microcapsules comprise electrically conductive grains 22-1, 23-1 which are covered with a dielectric 22-2, 23-2 and may consist of a metal selected from the group consisting of copper, nickel, silver, gold, a solderable metal alloy or an insulator, for example tin oxide, which is covered with an electrically conductive metal, e.g., silver. The way in which microcapsules can be produced is known, for example, from "JOURNAL OF MATERIALS SCIENCE" 28 (1993), pages 5207-5210 which is incorporated herein by reference. The dielectric 22-2, 23-2 used may be an insulating enamel, which may also act as a soldering flux.

[0017] For the soldering operation, layers of solder 25, 27, for which a metal selected from the group consisting of tin, indium, gallium, or a metal alloy with a low melting point may be used, are provided on the pads 11, 21 in order to produce the electrically

conductive connection between electronic circuit system 10 and substrate 20. The layers of solder 25, 27 are preferably produced by selective electroless deposition on the pad surfaces, so that it is possible to produce sufficiently planar surfaces.

[0018] In accordance with the method according to the present invention, microcapsules 22-1, 22-2, 23-1, 23-2, which are embedded in the adhesive 24 or a polymer film, which is not specifically shown in Figure 4, are introduced between the electronic circuit system 10 and the substrate 20. They are then compressed together under such a force that the dielectric 23-2 of microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another is broken open. After compression, the arrangement is heated to a temperature which is above the melting point of the solder material of the layers of solder 25, 27. In the process the molten solder comes into contact with material of the electrically conductive grains 23-1 of the microcapsules 23-1, 23-2 and a metallic bond having good electrical conductivity is produced.

[0019] Microcapsules 22-1, 22—2 in lateral spaces between pads 11, 21 remain unaffected by the compression operation and therefore their dielectric 22-2 remains intact. The result of this is that lateral short circuits are prevented. Therefore, the electromechanical connection according to the invention is anisotropically conductive in the sense explained above.

[0020] It is particularly preferred if a diffusion-soldering method is used for the soldering. In this method, a metallic bond which is able to withstand high temperature is produced using a low-melting solder as a result of the solder metal forming an intermetallic phase which is able to withstand high temperatures and is very mechanically

stable, with high-melting metals which are to be connected. In the process, the low-melting solder metal is completely transformed, i.e. passes completely into the intermetallic phase. A soldering method of this type is disclosed in United States Patent No. 5,053,195, wherein the layers of solder 25, 27 have a thickness of the order of magnitude of about 10 μm, preferably of less than about 10 μm, and consist, for example, of tin. The electrically conductive grains 23-1 or the metallic layers of grains in the form of metallized insulators, and if appropriate the pads 11, 21, consist, e.g., of copper or nickel. When contact is made between the metal of the grains during the diffusion-soldering method, the tin is completely transformed into intermetallic phases, which are denoted by 26, 28 in Figure 4. As has been explained above, the joint which is formed in the process has a significantly higher melting point than the solder metal and better mechanical properties, such as high tensile strength and freedom from creep. It is important in a soldering process of this type that a single layer of microcapsules is situated between the pads 11, 21 and the pad surfaces are sufficiently planar. Then, all the microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another are compressed, so that their electrically conductive grains 23-2 or their electrically conductive parts come into contact with the solder metal.

[0021] A single-layer structure can be produced particularly successfully if the microcapsules 22-1, 22-2, 23-1, 23-2 are previously embedded in a polymer film. The manner in which films with embedded microcapsules of this type can be built up and produced is taught in 1992 "IEEE", pages 473 to 480 and 487 to 491. A film of this type ensures the lateral insulation of the microcapsules 22-1, 22-2, 23-1, 23-2 and can act as a

spacer. Shaped parts which match the surfaces which are to be connected can be produced. The adhesive 24 can then be dispensed with, if appropriate.

[0022] It should be mentioned once again that the configuration described above is not specifically illustrated in Figure 4. Also, soldered joints between pads 11, 21 which are inactive in the sense mentioned above and microcapsules 23-1, 23-2 without any adhesive 24 being present are not specifically illustrated in Figure 4. However, in Figure 4 it would be possible, for example, for the two pads 11, 21 shown on the right-hand side of the drawing to be regarded as "inactive" pads and for the two pads 11, 21 situated on the left-hand side of the drawing to be regarded as "active" pads.

[0023] In a further preferred embodiment of the present invention, it is possible to use microcapsules 22-1, 22-2, 23-1, 23-2 which at least in part consist of a solder metal. According to a variant of this embodiment, the electrically conductive grains 22-1, 23-1 consist entirely of solder metal, in which case a metal selected from the group consisting of tin, indium, gallium or a soft-solder alloy can be used as solder metal. In this case, a solderable metal which may be a metal selected from the group consisting of copper, nickel, silver or gold is used as material for the pads 11, 21 of the electronic circuit system 10 and substrate 20. Also in this embodiment, the electrically conductive grains 22-1, 23-1 of the microcapsules 22-1, 22-2, 23-1, 23-2 are surrounded by a dielectric 22-2, 23-2 in the form of a layer of insulating enamel. This layer of insulating enamel additionally prevents in particular electrically conductive grains 22-1 in the lateral spaces between pads 11, 21 of electronic circuit system 10 and substrate 20 from flowing together when heated during the soldering process and therefore prevents short circuits in the lateral direction.

[0024] Since the solder material of the electrically conductive grains 23-1, 23-2 of the microcapsules 22-1, 22-2, 23-1, 23-2 becomes liquid during the soldering process, and therefore the layer of insulating enamel breaks more easily, the pressure required to break open this layer between pads 11, 21 which face one another is not as high as in the first embodiment of microcapsules. When the solder material makes contact with the material of the pads 11, 21, the soldered joint is formed, and therefore electrical and mechanical contact is made.

[0025] Since the microcapsules 22-1, 22-2 in the lateral spaces between pads are not compressed, their layers of insulating enamel 22-2 remain intact. When using an adhesive 24, these microcapsules are held together either by the adhesive, or when embedded in a polymer film, and cannot flow out. Therefore, in this embodiment, the diffusion-soldering method explained above is particularly advantageous. The electrically conductive grains 22-1, 23-1 of the microcapsules 22-1, 22-2, 23-1, 23-2 may, for example, consist of tin and the pads 11, 21 of electronic circuit system 10 and substrate 20 may consist of copper or nickel. If the electrically conductive grains of the microcapsules have a diameter of less than 10 μm, the tin is completely transformed into the intermetallic phase 26, 28 when contact is made between the solder metal and the pad metal. In turn, an electromechanical connection with a melting point which is significantly higher than that of the solder metal, and therefore excellent mechanical properties, such a high tensile strength and freedom from creep is formed.

[0026] Electrically conductive grains with a small diameter of the order of magnitude of 10 μm and preferably less than 10 μm are advantageous for a number of reasons. First, the thicker the electrically conductive grains the longer the process of chemical

transformation takes during the diffusion soldering. For example, with a diameter of about 40 μm the reaction takes over half an hour. With diameters of less than about 10 μm the reaction time is of the order of magnitude of minutes. Second, the pads 11, 21 have to be sufficiently thick to be able to provide sufficient metal for the transformation reaction. When using electrically conductive grains having the preferred diameters there is relatively little solder metal available so that a correspondingly small amount of pad metal needs to be available for complete transformation. Third, small diameters of the electrically conductive grains are of benefit to finely structured contacts which are advantageous in particular for integrated semiconductor circuits with a high level of integration. Fourth, the diameter of the electrically conductive grains determines the thickness of the soldered joint. Thin soldered joints have a better fracture behavior. With a thickness of less than about 5 μm the joint has an elastic action when bent, whereas if its thickness is greater than about 10 μm it becomes brittle, so that stress cracks may easily form.

[0027] In a modification of the embodiment described above, the electrically conductive grains 22-1, 22-2 of the microcapsules 22-1, 22-2, 23-1, 23-2 may not consist entirely of solder metal, but rather may consist of a metal core which is covered with solder metal. This may, for example, be a copper core which is covered with a layer of tin solder. If the tin solder is deposited electrolessly in a tin exchange bath, the top layer of the copper core is replaced by a correspondingly thin layer of tin. A typical thickness of the layer of tin is of the order of magnitude of about 200 nm.

[0028] The use of electrically conductive grains of this type, including their use in the mechanical and electrical connection of objects, is disclosed in 1996 "Electronic

Components and Technology Conference", pages 565-570 which describes an electrically conductive adhesive material which comprises a conductive filler powder which is covered with a metal with a low melting point (solder metal), a thermoplastic polymer, and further minor organic additives. The filler grains are coated with the metal of a low melting point which, when producing a connection between objects, is melted in order to produce a metallurgical bond between adjacent filler grains and between filler grains and metallic connection elements on the objects which are to be connected. A connection of this type corresponds to the arrangement shown in Figure 1. In this case, however, the problems explained above with regard to the adhesive formed by the polymer and with regard to the amount of electrically conductive grains used may be encountered.

[0029] In the two embodiments discussed above, electrically conductive grains 22-1, 22-2 are covered with a dielectric 22-2, 23-2 in the form of a layer of insulating enamel. It should be noted that the fact that the electrically conductive grains may for their part be of two-part form is not specifically illustrated in Figures 2 to 4.

[0030] One advantage of electrically conductive grains 22-1, 23-1 in the form of metal cores which are covered with solder metal is that the soldering process, which is once again preferably in the form of the diffusion-soldering process, takes place very quickly and precisely on account of the overall very thin layer of solder. A further advantage is that even in microcapsules 22-1, 22-2 in the lateral spaces between pads 11, 21, which are therefore not in contact with pads 11, 21, the solder reacts with the core metal and is transformed into an intermetallic phase. Therefore, microcapsules of this type are firmly stable at temperatures which lie well above the melting point of the solder, since they can no longer become liquid.

[0031] Furthermore, on account of the low thickness of the layers of solder of the electrically conductive grains and the resultant relatively small quantity of solder metal, the thickness of the pads 11, 21 can be reduced since a correspondingly small quantity of pad material is required for complete transformation of the quantity of solder. A further reason for using layers of solder of small thickness is that it is not necessary for the pads to be raised since the solder of the electrical conductive grains cannot "run out" when the layer of insulating enamel breaks open since the low layer thickness means that the solder adheres to the surface of the metal core, providing good wetting of the latter. Accordingly, in all the microcapsules 22-1, 22-2, 23-1, 23-2, both those in lateral spaces between pads 11, 21 and those between pads which face one another, it is no longer possible for any liquid solder, which leads to short circuits, to form at operating temperatures of the arrangement. Hence electromechanical contact with the pads 11, 21 results from the reaction of the solder of the electrically conductive grains 23-1, 23-2 with the metal of the pads 11, 21.

[0032] A further advantage in the embodiments with electrical conductive grains 22-1, 23-1 comprising metal other than solder metal and layers of solder 25, 27 on the pads 11, 21, as well as electrically conductive grains comprising metal cores covered with a layer of solder, is that it is possible to produce particularly thin solder layers, which can be controlled accurately, during the diffusion-soldering method, in the form of intermetallic phases 26, 28.

[0033] In the embodiments described above, the microcapsules 22-1, 22-2, 23-1, 23-2 (apart from the variant involving the embedding in a polymer film) can be processed with an insulating liquid which may be the above-mentioned adhesive 24 or a flux to form a

paste. In the case of the adhesive it is possible to combine the advantages of an adhesive bond and of a soldered joint. This adhesive bond ensures additional mechanical stability, and the soldered joint ensures reliable electrical connection.

[0034] To summarize, according to the present invention it is possible to achieve a creep-resistant connection, since during the preferred diffusion soldering the solder material (as a thin layer on the microcapsules or the connection elements on the electronic circuit system and the substrate) is completely changed into the intermetallic phase, i.e. no residues of solder material remain. The thin layers of solder material ensure that the soldering process takes place relatively quickly. Furthermore, the large quantity of microcapsules which is possible even with small connection element structures means that reliable electrical connection in combination with good thermal conduction and (on account of the mechanical soldered joint via the soldered microcapsules) a significantly more reliable mechanical connection compared to a pure adhesive bond is ensured. Finally, high thermal stability of electromechanical connection is also ensured since the overall connection operation can be designed in such a way that no residues, such as for example insulating residues of metal oxides, glass or ceramic or binder, remain in the connection.

ABSTRACT OF THE DISCLOSURE

In an electromechanical connection between electronic circuit systems (10) and substrates (20), these components are mechanically connected fixedly to one another, their electrical connection elements (11, 21) are connected to one another in an electrically conductive manner via microcapsules (23-1, 23-2), which comprise grains (23-1) which are coated with a dielectric (23-2) and, at least in part, are electrically conductive, and there is an electrically conductive soldered joint (25 to 28) between microcapsules (23-1, 23-2) with broken-open dielectric (23-2) and the electrical connection elements (11, 21).

FIG 1

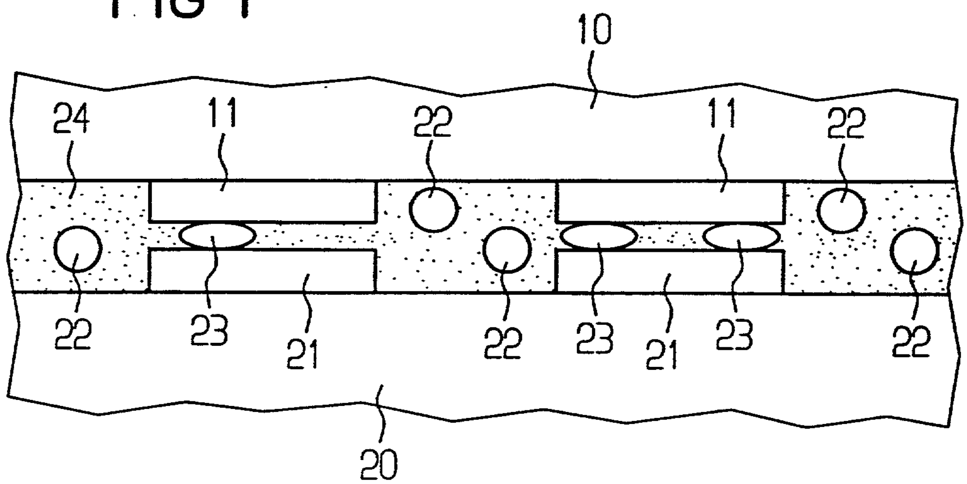


FIG 2

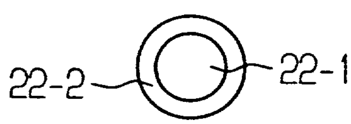


FIG 3

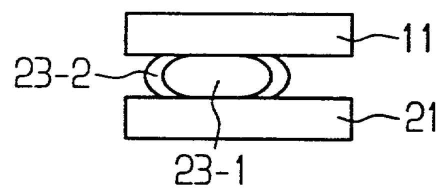
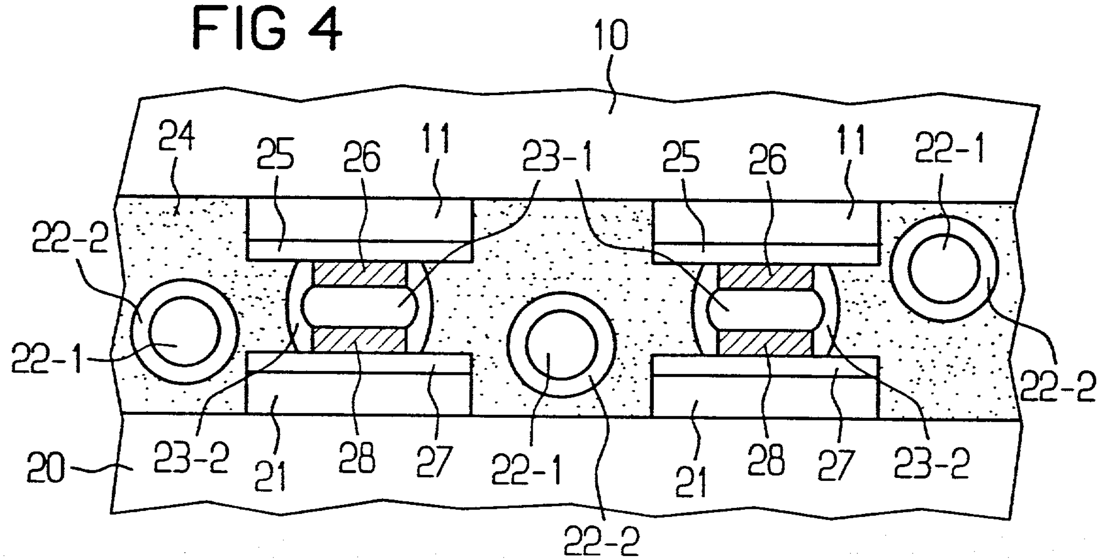


FIG 4



Declaration and Power of Attorney For Patent Application

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Elektrisch-mechanische Verbindung zwischen elektronischen Schaltungssystemen und Substraten, sowie Verfahren zu deren Herstellung

Electrical-mechanical connection between electronic circuit systems and substrates and method for the production thereof

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 19.06.2000 als
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Priorität beansprucht

Priority Claimed

19930189.1 (Number) (Nummer)	DE (Country) (Land)	30.06.1999 (Day Month Year Filed) (Tag Monat Jahr eingereicht)	☒ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein

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PCT/DE00/02012 (Application Serial No.) (Anmeldeseriennummer)	19.06.2000 (Filing Date D, M, Y) (Anmeldedatum T, M, J)	anhängig (Status) (patentiert, anhängig, aufgegeben)	pending (Status) (patented, pending, abandoned)
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